THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

OCTOBER 1956

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

10 CHESTERFIELD STREET . LONDON . W1 Telephone : GROsvenor 5254/9

Vol. 35, No. 10 *Price 10/-* *October 1956*

CONTENTS

plan with Birmal

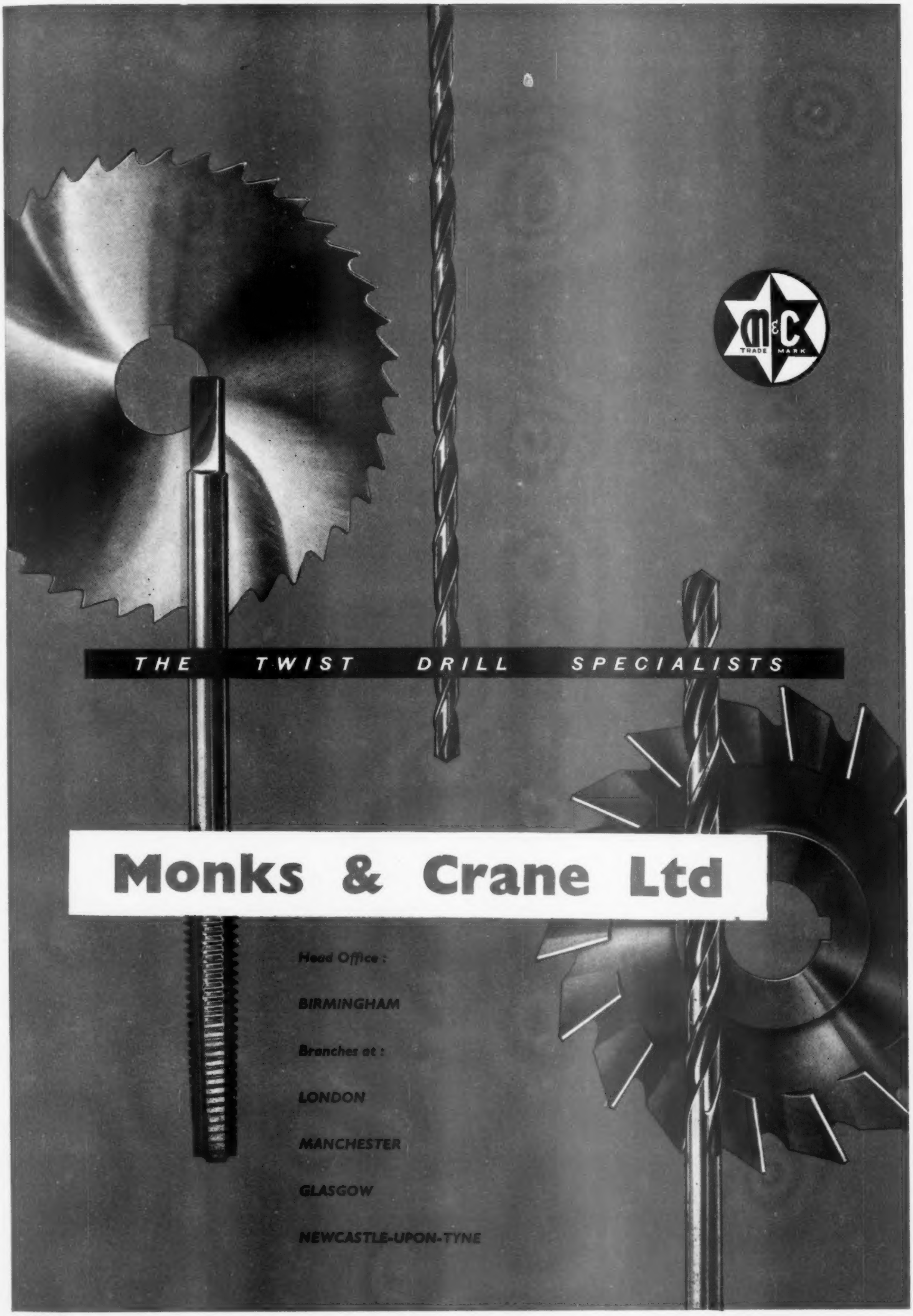
Air intake casing
for the Proteus engine.
By courtesy of The Bristol Aeroplane Company Limited.

You get more than a casting from BIRMAL

This is a casting. A very exclusive casting. Its life—in flying hours—is far more certain than the life of any human being. How is such certainty attained? Where does it begin? Surely, with the materials used, and with the men who fashion them? It begins with accuracy, consistency and foundry 'know-how'. Where light alloy castings for the Aircraft Industry are concerned, it is not too much to say that certainty begins with Birmal.

Birmingham Aluminium Casting (1903) Co. Ltd.

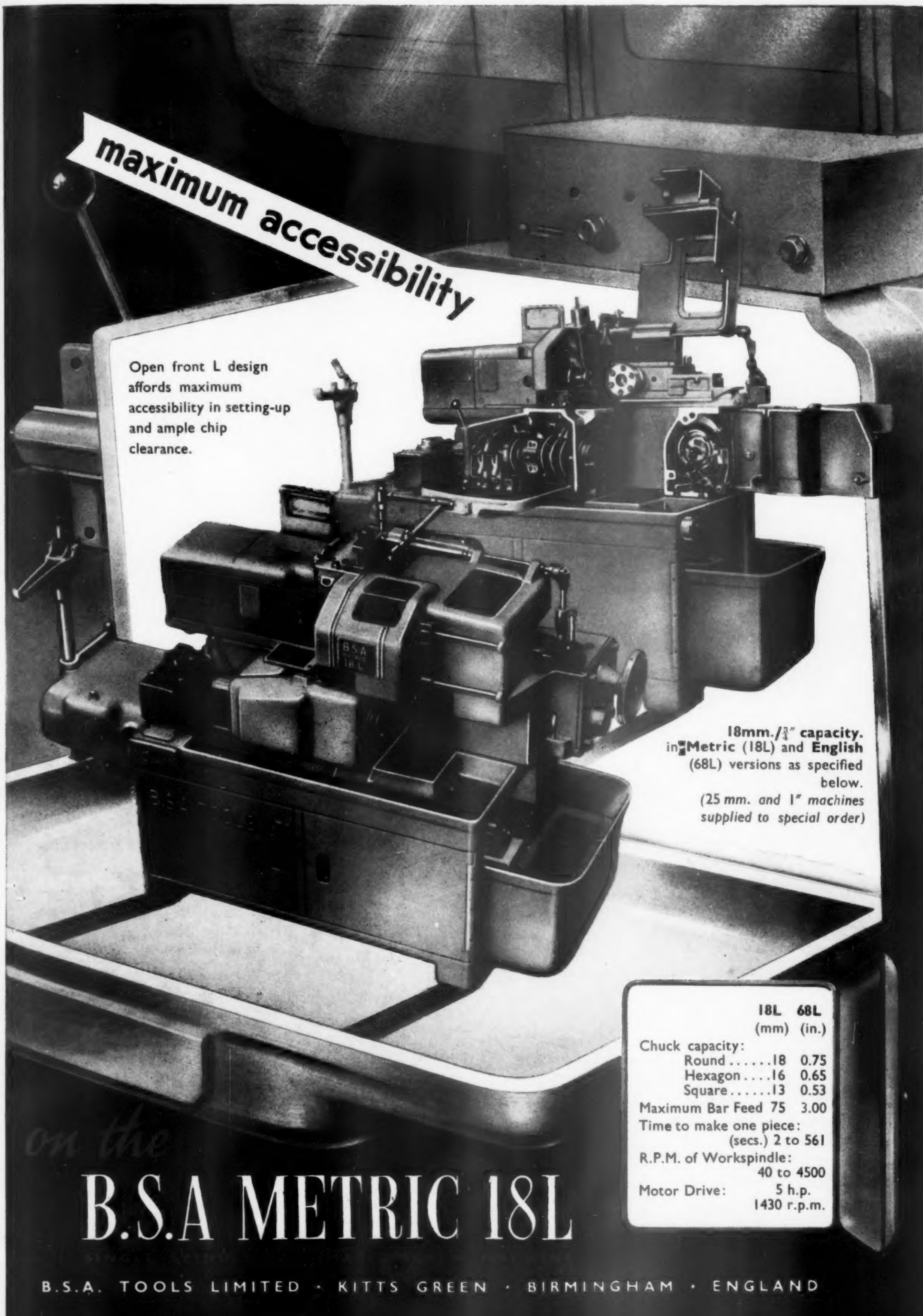
BIRMID WORKS SMETHWICK BIRMINGHAM 40


M&C
TRADE MARK
THE TWIST DRILL SPECIALISTS
Monks & Crane Ltd
Head Office :
BIRMINGHAM
Branches at :
LONDON
MANCHESTER
GLASGOW
NEWCASTLE-UPON-TYNE

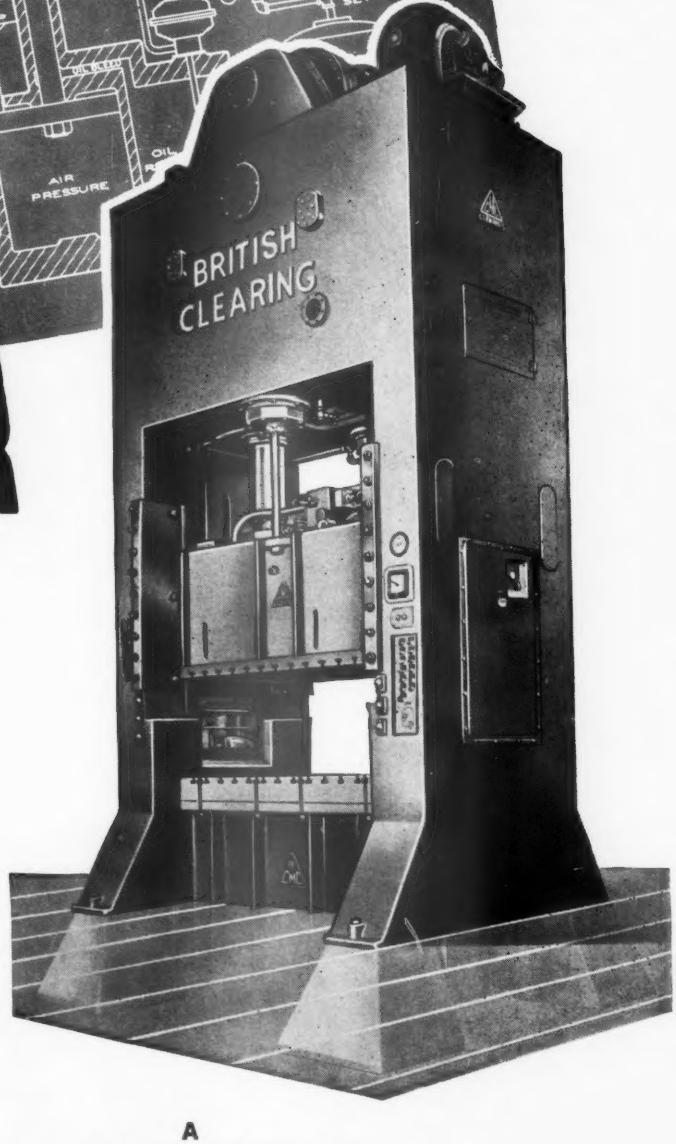

CKD
PETER KNEEBONE


Measured
Delivered
and
THEN
Rejected


from any angle . . .
AMERICAN STANDARDS
ENGLISH STANDARDS
UNIFIED STANDARDS
METRIC STANDARDS
UNBRAKO
Always right !
UNBRAKO SCREWS COST LESS THAN TROUBLE
Unbrako is undoubtedly the world's finest screw, a precision product that does a job better than it has ever been done before. Unbrako screws are the result of Quality Control carried out during the entire process of manufacture, involving both material and dimensional inspection and Physical Laboratory tests. Our service department will be pleased to advise you on the type best suited to your requirements.
UNBRAKO SOCKET SCREW CO., LTD · COVENTRY · ENGLAND


maximum accessibility
Open front L design affords maximum accessibility in setting-up and ample chip clearance.
18mm./¾" capacity. in Metric (18L) and English (68L) versions as specified below.
(25 mm. and 1" machines supplied to special order)
18L 68L
(mm) (in.)
Chuck capacity:
Round......18 0.75
Hexagon....16 0.65
Square......13 0.53
Maximum Bar Feed 75 3.00
Time to make one piece: (secs.) 2 to 561
R.P.M. of Workspindle: 40 to 4500
Motor Drive: 5 h.p. 1430 r.p.m.
on the
B.S.A METRIC 18L
B.S.A. TOOLS LIMITED · KITTS GREEN · BIRMINGHAM · ENGLAND

Another New
BRITISH CLEARING DEVELOPMENT



A REAL OVERLOAD PROTECTION DEVICE

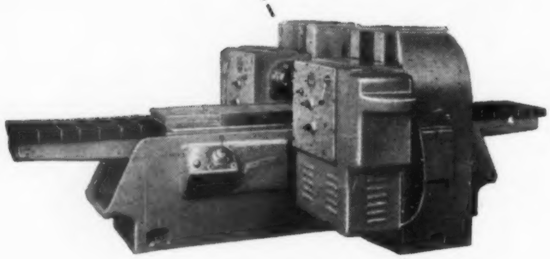
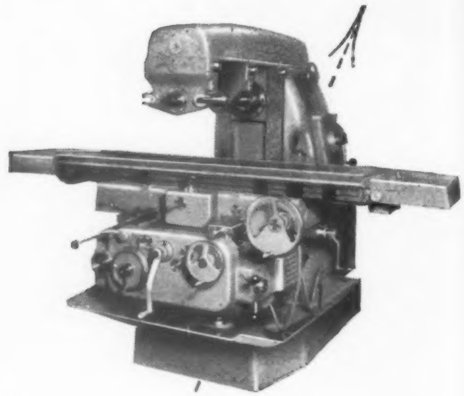
The British Clearing Hydraulic Safety Overload Protection Device has been developed to provide mechanical presses with a much needed safeguard against excessive overloads near the bottom of the stroke. This device provides a cushion of hydraulic fluid under pressure beneath the slide adjustment mechanisms. This hydraulic cushion prevents the press from building up tonnage beyond a pre-set pressure through the last ½" of stroke. The unit is entirely enclosed within the slide. The tonnage setting is regulated at floor level and warning indicator lights are located on the main control panel.

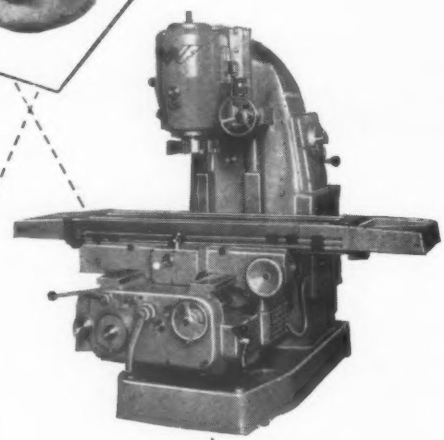
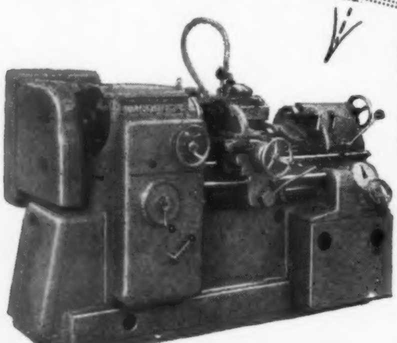
A VICKERS-ARMSTRONGS PRODUCT

ROCKWELL MACHINE TOOL CO. LTD. WELSH HARP, EDGWARE RD., LONDON, N.W.2. TEL: GLADSTONE 0033

ALSO AT BIRMINGHAM—TEL: SPRINGFIELD 1134/5 · STOCKPORT—TEL: STOCKPORT 5241 · GLASGOW—TEL: MERRYLEE 2822

B.C.O

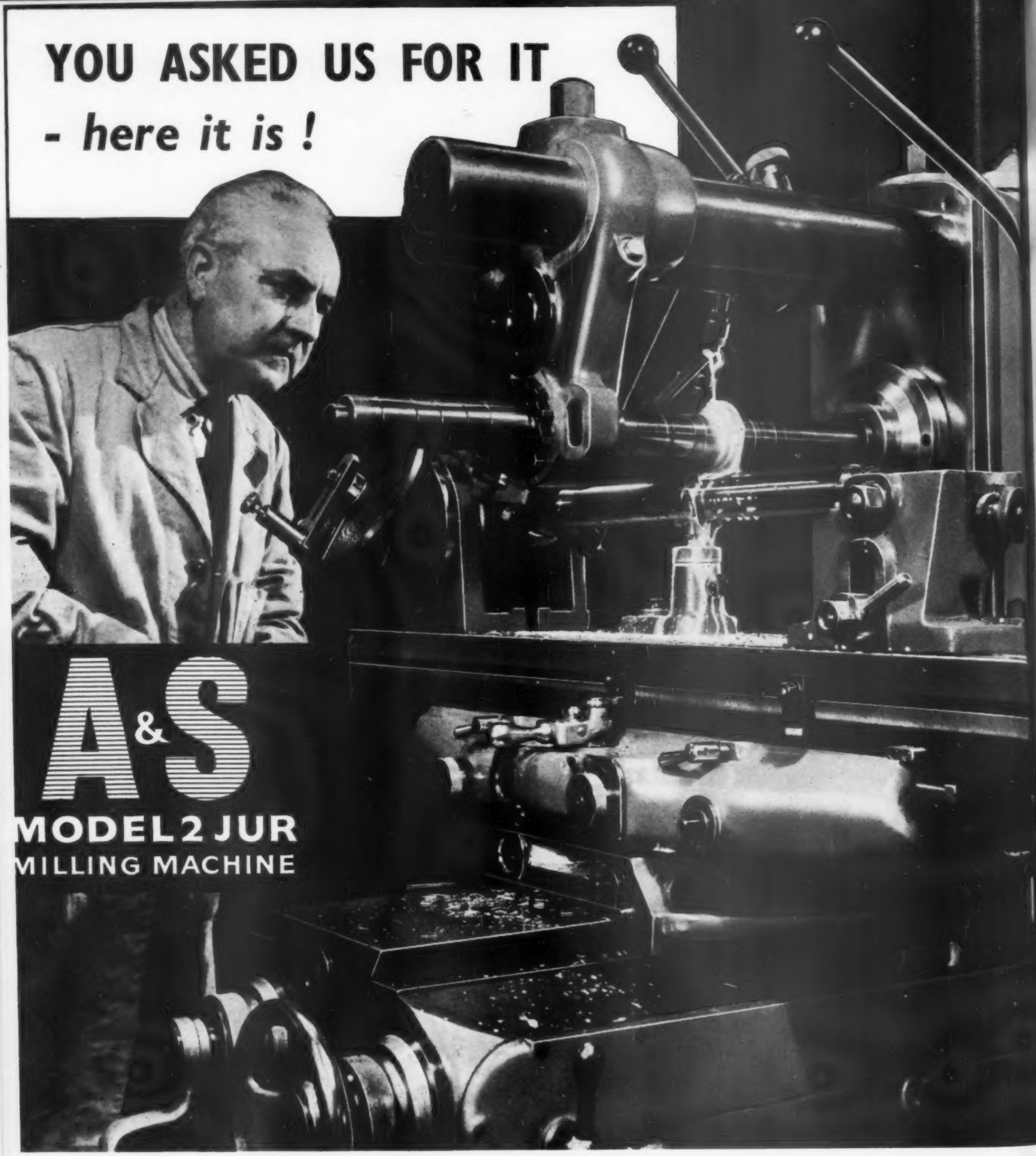



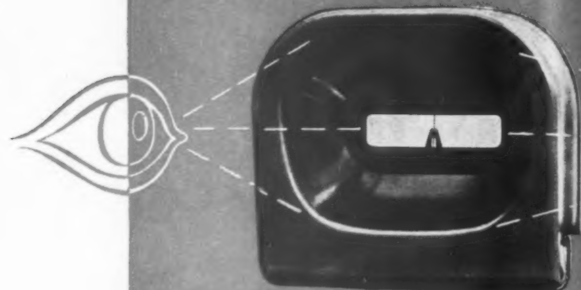

STANLEY HOWARD LTD
73 DEVON STREET
SALTLEY BIRMINGHAM 7
Tel: ASTon 1275


DELIVERY
OFF THE SHELF
AGAIN!
B·A·C
WORLD'S BEST DRILL BUSH
BRITISH AERO COMPONENTS LTD. MONTAGUE RD., WARWICK. TEL. 320

Cogen


YOU ASKED US FOR IT
- here it is !
A&S
MODEL 2 JUR
MILLING MACHINE

ACCURACY at a glance



This jig boring machine having large capacity performance incorporates built-in standard scales ensuring permanent accuracy of all co-ordinate settings.

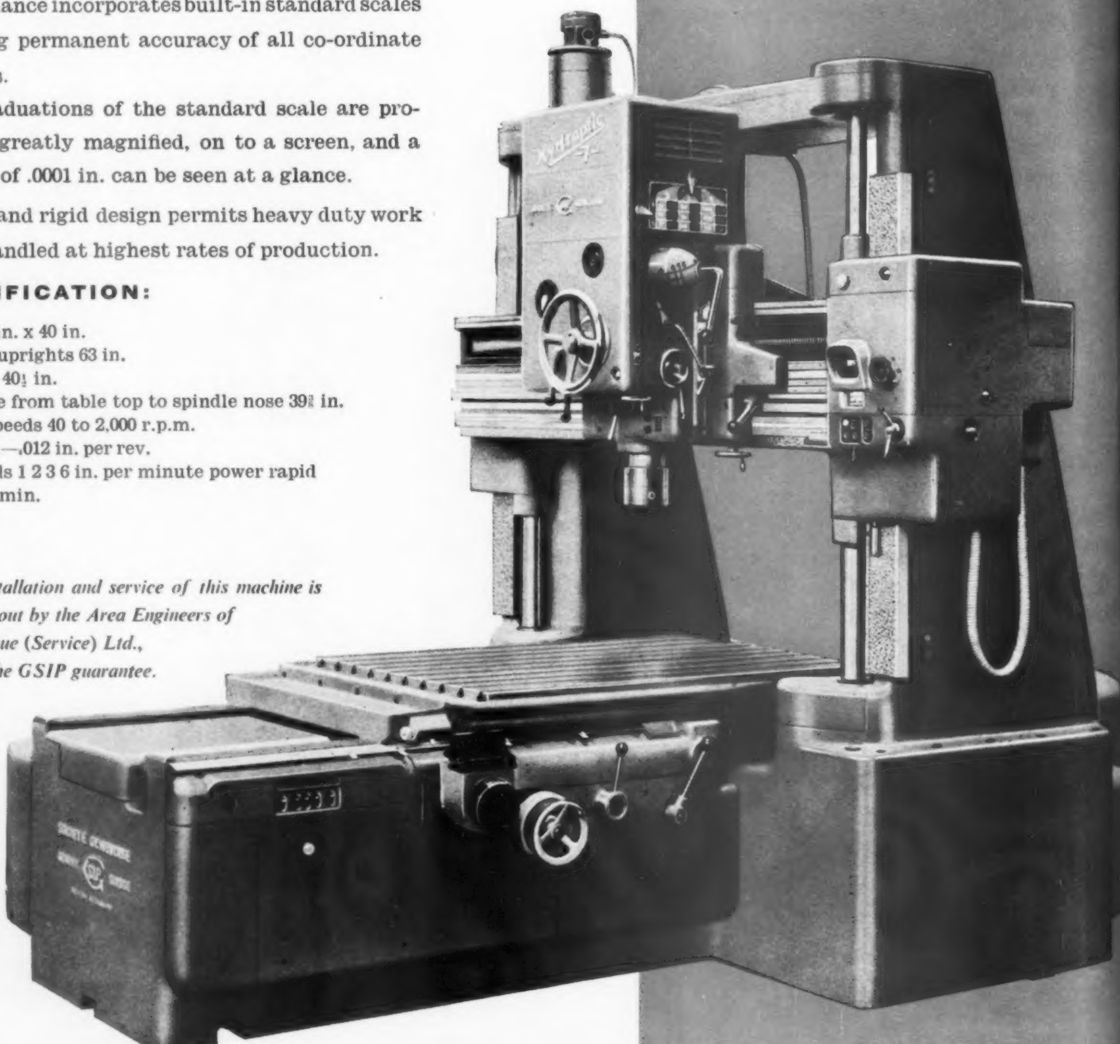
The graduations of the standard scale are projected, greatly magnified, on to a screen, and a setting of .0001 in. can be seen at a glance.

Strong and rigid design permits heavy duty work to be handled at highest rates of production.

SPECIFICATION:

Working range 55 in. x 40 in.
Distance between uprights 63 in.
Table size $61\frac{7}{8}$ in. x $40\frac{1}{2}$ in.
Maximum distance from table top to spindle nose $39\frac{3}{8}$ in.
Vertical spindle speeds 40 to 2,000 r.p.m.
8 spindle feeds .001—.012 in. per rev.
Power milling feeds 1 2 3 6 in. per minute power rapid traverse 58 in. per min.

The installation and service of this machine is carried out by the Area Engineers of Sogenique (Service) Ltd., under the GSIP guarantee.



GSIP HYDROPTIC 7P

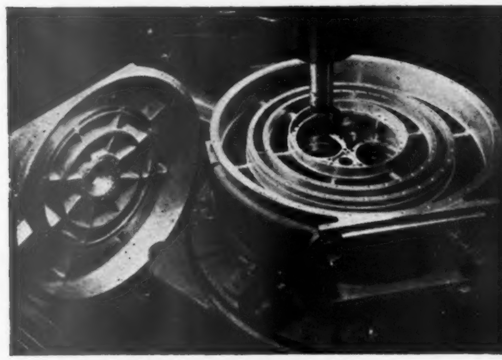
Guaranteed setting accuracy .0002 in.

Settings are performed with amazing speed and utmost simplicity.

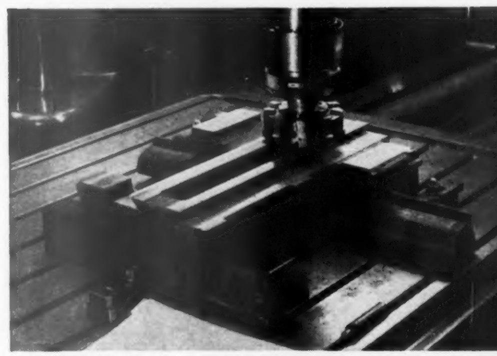
Approximate settings are provided by external scales divided into 0.1 in. Further decimal figures are read to 0.0001 in. on the micrometer head of each viewing screen the movements of which control the position of the reticle on the screen. Slow motion controls of the table and spindle saddles enable accurate settings to be obtained by centering the appropriate projected standard scale line between the indices of the reticle.

For literature or further information please write or telephone Temple Bar 2126.

Milling a headstock, fully machined on the 7P.



Boring light alloy gear reduction housing for jet engines.

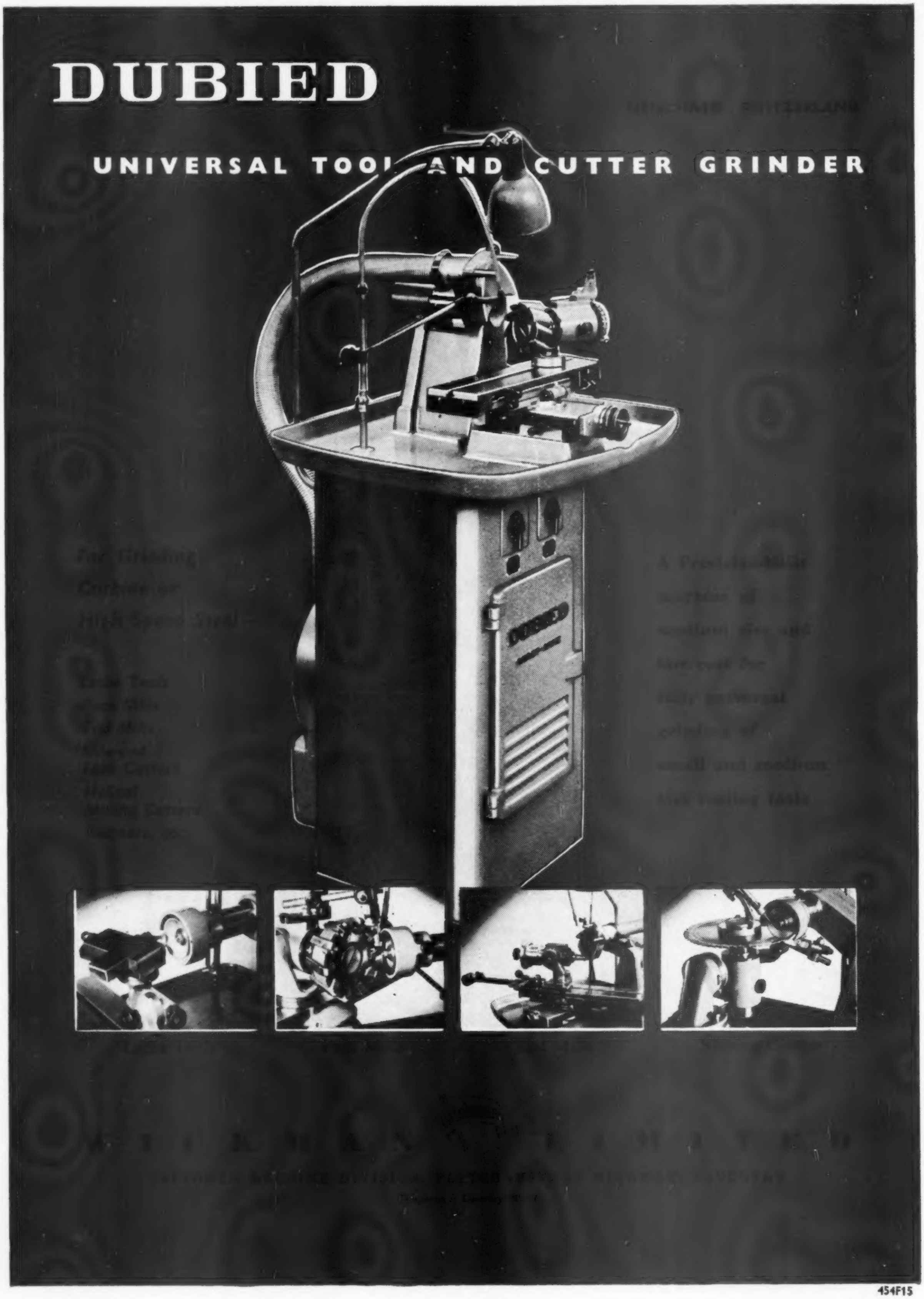


Milling a large lathe cross-slide, saving hand-scraping

Machining a housing fully machined on the 7P.

SOCIETE GENEVOISE LTD

5-6 BRETTENHAM HOUSE · LANCASTER PLACE · LONDON W.C.2


DUBIED
UNIVERSAL TOOL AND CUTTER GRINDER
For Grinding
Carbide or
High Speed Steel
A Precision-built
machine of
medium size and
low cost for
fully universal
grinding of
small and medium
size cutting tools
DUBIED

454F15

The Institution of Production Engineers Journal
VOL. 35 NO. 10 OCTOBER, 1956

The Impact of Automation on Society

by T. BURNS, B.A.(Bristol),

Senior Lecturer, Department of Social Study, University of Edinburgh.

This Paper formed the basis of a lecture delivered to the Institution's 1956 *Summer School at Ashorne Hill, on* 28*th July last.*

EVERYBODY who discusses automation is aware that it is a new word for developments as old as industry itself, and yet there is an irresistible tendency to make it a crisis point, to have conferences about it, to add it to the issues between workers and management. What are the social pressures making for this dramatisation ? Possible clues lie in the following :

(i) Occupational status has come to be the chief designation of social status. Work places are now the institutions with the most clearly defined hierarchy of status and authority.

(ii) Outside the workplace differences in status as reflected in clothes, leisure activities, symbols, possessions, are becoming elided. The traditional social structure of clear-cut class divisions is being overlaid by another structure of élite group and mass audience connected by the mass communication industries.

(iii) We remain a society dominated by the idea of success. Possibilities of success are becoming more and more restricted to educational and occupational promotions.

So more and more of the social and psychological pressures now bearing on people are concentrated in workplaces, which are becoming the main arena for political and social as well as economic conflicts. The problems of modern states are largely industrial. No problem affecting industry in general, or large sectors of it, can remain only technological or managerial.

In discussing automation in the factory, we can take it as established ground that what we are talking about are the changes likely to arise, or be needed, from an accelerated expansion of :

(a) automatic machining and transfer ;

(b) automatic process, product and quality control ;

(c) computer-controlled machining ;

(d) rapid processing of information about costs, progress, stores, etc.

Of these, the third is by far the most important, since it will itself tend to accelerate the rate of technological advance. In what I have to say, my eye will be on the engineering industry, since it is here that the impact of *all* four developments will be felt.

We can also take it that there are certain changes which may be fairly safely counted on. These are :

(i) A large increase in the functions of programming, production, costing and planning operations.

(ii) A considerable change in the skills required of operatives, and a much higher standard of technical competence in all branches of management.

(iii) A considerable movement away from divisions of labour into individual, semi-autonomous jobs, and towards interlocking service functions. This applies both to labour and management.

(iv) A development of plant-hiring schemes, as the way out of the high capital commitments which might not pay off by users and out of the competition among insurance companies, banks and trusts for the safer industrial shares. And, hence, a greater than ever need for cost control, and for flexibility in equipment and resources of skill. Also, an extension of the servicing aspect of functions as between makers and users of equipment.

Directly we go beyond these, we are on highly speculative ground. What follows is a review of *some* of the possible trends and implications.

Skills and Labour

Present discussion about the social consequences of technical change hinges inevitably on technological unemployment. Until the Standard affair the only evidence of large-scale reductions in staff as a result of the introduction of automatic devices was in the sector of office work, but clearly the fear of technical unemployment does enter into the minds of trade unionist and politician. On the other hand, there are plenty of grounds for thinking that the technical structure of industry at present covers such a wide range that, for some decades, the development of automatic devices will tend to provide increased employment opportunities, especially among skilled workers. For many years to come, the main efforts of such industry as will be affected by automatic methods will be towards increasing speeds and towards reducing costs by increasing production. Moreover, the quickest developments may be expected to occur in the computer-controlled machine tool. When this is fully developed and available, it will speed up the development and the production of prototype models and the production of tools, and the *rates of progress from one product to another.*

In this situation there is probably a considerable fluctuation in the demand of a particular industry or a particular factory for individual skills, a fluctuation which would be wider than that in the total demand for labour. It might well be that an individual factory will need a complement of craftsmen who could act as fitters, maintenance men, tool-makers, inspection controllers, at different times of the year.

Moreover, this adaptability will be called for in a wider sense. The introduction of a punch-card system with computers into large offices can reduce office staff by 80% or 90%, yet there may very soon appear needs for information which is now wanted because it can be analysed and used in a reasonably short time by the new methods.

Two possible consequences of the development of automation therefore are :

1. a larger population of skills than of work people ; and
2. a heightened need for adaptability and mobility of labour.

Training

The production of the necessary number of skills, which will have to be greatly in excess of the number of men employed, will require industry to undertake the job of training much more soundly and on a vastly bigger scale than anything it has at present envisaged. This applies also to management skills and to technologists. We are at present going through an interim period in which industry is still hoping that society, through the general educational establishments of schools, universities, and technical colleges, will provide it with the basic skills that it needs. The inability of such institutions to provide skills in sufficient quantities, as well as the increasing distortion of the declared aims of such institutions by these burdens, will soon throw the onus of producing skills for industry back where it belongs.

" Professional ", as Against " Scientific ", Management

We have by now come to the end, it appears, of a long-term trend of functional differentiation which has resulted in the break-down of the job of management into

a number of fairly clearly defined specialisms. These are now come to be regarded in the light of individual careers as works accountants, personnel managers, supervisors, sales managers, development engineers and so forth. One consequence of these distinctions is not only that the individual manager approaches the total task of the firm from the particularist standpoint of his special technique ; it also has the effect of the functional specialist regarding himself as a person hired by the firm to do a special job. He is, so to speak, not a member of the management of the firm so much as an accountant, estimator or planner, etc., under a special contract arrangement with the firm by which he does their accounting, estimating or planning in return for a salary.

In the new situation, this kind of management by a system of sub-contracts could well be the biggest check on the progress of the individual firm and even of an industry. The combination of very high costs and flexibility which new systems would involve will require the continuous rapid assessment of the costs of all the factors in relation to the sales cycle of product ranges, and the potential employment of the skills and equipment of the firm.

This situation must require far greater degrees of co-ordination between what we have come to regard as functional specialisms than ever before, and there will have to be a new basis of training and qualification for management merely in order to provide a common language and a common scale of values for the choices presented to management. In the new situation, programming will be all-important, and this will have to rely on a constant flow of easily assimilated information about what is going on in the factory.

(It might be added here that ecological factors play a part which is all too often ignored. The position of the office block, fitted out with South Bank interiors and furnishings, and separate from the factory, with a thin scatter of departmental managers in the works itself, militates very strongly against the kind of co-ordination which is even now necessary and will become more so. The placing of the management staff will have to be worked out with as much care, and its communications with the whole plant and with the market and other contexts of the works made as effective as is the case in a ship or any other unit which depends for its survival on co-ordination of control and the flow of information.)

All this involves a new professional outlook in management, one in which each person will see himself as a member of the organisation and will see his work as a contribution to the total task. It will require, that is, something of the outlook of a worker in a professional group, as in the case of doctors or scientists.

The skilled worker will clearly become less and less of a manual operative and more and more of a machine controller and maintainer, more and more also of a technician in the sense in which it is used in laboratory work ; he will also become less of an appurtenance of the simple machine. The need for acquiring a range of skills and for changing from one kind of activity to another will not be met adequately unless the worker himself grasps fully his particular place in the organisation and the meaning behind the changes required of him. He will become, in other words, not so much an operative controlled by management as an auxiliary executive. If this idea is accepted and is linked with the point made above about the need for industry to produce its own skills of all kinds, it will be appreciated that there will have to be a re-alignment of the relationship between manager and worker. This might be achieved in terms of the inclusion of the skilled worker in the management structure.

Conclusions

Summarising, the possible repercussions of automation on people inside industry are :

(a) a much greater need for information, for people to collect and process it ;

(b) a need for workers with multiple skills ;

(c) a need for managers with more and more varied technical qualifications, and a need in them for a "professional" as against a "specialist" outlook ;

(d) a need for more elaborate forms of programming, etc., and for more highly organised management structures ;

(e) a breakdown of traditional status divisions between managers and workers.

(*concluded on page* 618)

POSITIONAL CONTROL AND ITS POSSIBLE APPLICATION TO AUTOMATION

by J. D. OATES, B.Sc., A.M.I.Mech.E.

and A. T. GRANGER, B.Sc., A.M.I.E.E.

Presented to the North Eastern Section of the Institution, 20th February, 1956.

Mr. Oates was educated at Bradford Grammar School and at the University of Leeds, where he graduated with second class honours in Mechanical Engineering in 1941. He joined Rotol Ltd., where for a period of four years he worked on engine governing systems employing variable pitch propellers. For nine months he worked for John Miles & Partners (London) Ltd., consulting engineers.

In 1946 he joined Messrs. Vickers-Armstrongs (Engineers) Ltd., at Newcastle, where he has been chiefly occupied in the design and development of the servomechanisms and other equipment associated with the stabilisation and automatic position control of naval gunmountings. He has recently transferred within the firm to Harwell, where he hopes to continue his work on servomechanisms in the control of nuclear reactors for ship propulsion.

Mr. Oates.

Mr. Granger.

Mr. Granger was educated at West Hartlepool Grammar School and at King's College, Newcastle-upon-Tyne. He served a graduate apprenticeship at Vickers-Armstrongs, Ltd., Elswick, and joined the Research Department, where he is now responsible for the instrumentation of the various research projects. This includes the design and maintenance of suitable equipment, data recording, and work on servomechanisms.

He is interested in music and high quality recording.

POSITIONAL Control is a very broad subject which covers the movement of some selected object to a predetermined position. It is not a new thing. It dates back to times before Eve plucked the apple from the tree in the Garden of Eden. The very act of plucking the apple is positional control of the arm, hands and fingers. But this involves a human link and the scope of this Paper is limited to those positional controls which are mechanical in nature and which may be applied to tools in the machining and inspection in the engineering industry.

In the machining of material the aim is to produce in three dimensions that which has been portrayed by a draughtsman on a sheet of paper, by removing excess material from a blank or block.

In a very simple case, a turner may be required

to produce a parallel shaft to a given dimension. The turner measures the size of the virgin material and by successive gauging removes material so as to leave the shaft with the required diameter. In positional control it is possible for the required diameter to be obtained by the same or fewer cuts, the diameter to be reached at each cut being set by push buttons. Once the work has started the gauging is done continuously, so there is no stopping until the work is complete.

There is quite a broad choice available of methods of translating the blue-print into relative movement between the cutting tool and the material being machined. In many cases it is a question of first translating the blue-print into three dimensional co-ordinates, one or more of which is continuously varying according to some law, and then causing the tool and/or table to follow this law.

Where repetition is needed the blue-print may first of all be translated into a master shape which can then be copied on a copying machine.

In both these conceptions, a servomechanism governs the relative positions of the tool and table. A servomechanism may be defined as a system of controlling power whose output is governed by the difference between the command input and resulting output.

Basically, a servomechanism is depicted in Fig. 1.

In the diagram, the command input signal (which is the desired position) is passed through a differential which subtracts the output (which is the actual position). The resulting signal, the error, is amplified and passed to the driving motor which moves in such a direction as to reduce the error signal. The operation is continuous and whenever there is error there is a force available to reduce it. As the output is fed back and compared with the command input signal a servomechanism is often referred to as a feedback control.

The command and the output will be positions, measured in inches and fractions of an inch or in degrees and fractions of a degree. The signals in the remainder of the control may take various forms, other than displacement, such as voltage, current, pressure, flow, force, torque, etc., and this gives us a very great choice in the selection of components. Transducers are used to convert the displacement signals to these other parameters to suit the control system, as indicated in Fig. 1.

Error Measurement

The subtraction of output position from command position can be done in various ways. In cases where the command position signal is generated remotely from the output, the two positions are usually transduced into some electrical signal before subtraction.

However, if the input and output positions are not far apart the mechanical lever and gear differentials spring first to mind. Fig. 2 shows how the error can be obtained from levers for small reciprocating movements. In Fig. 3, the two upper shafts rotate in the same direction and difference in angular movement of these shafts produces angular movement of the lower shaft.

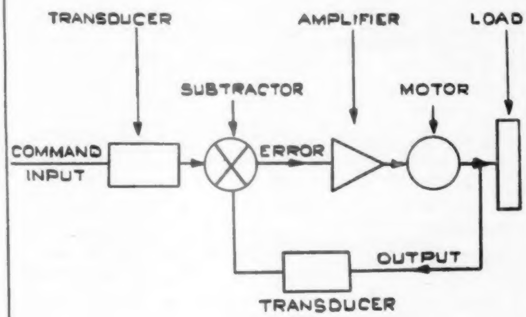


FIG. 1. BASIC SERVOMECHANISM.

In copying machines the difference can be converted directly to either a hydraulic or electrical signal.

In the hydraulic case, shown in Fig. 4, the error is measured as a valve opening, resulting in a rate of flow of oil past the valve lands. The valve can take different forms and if desired it can be arranged for the error to be measured as a pressure. It is not intended to distinguish between hydraulic and pneumatic systems, considering air merely as a more compressible fluid than hydraulic fluids.

FIG. 2. MECHANICAL DIFFERENTIAL-RECIPROCATING.

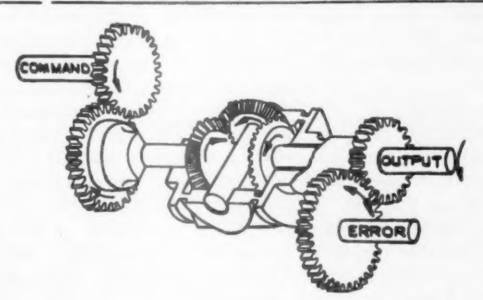


FIG. 3. MECHANICAL DIFFERENTIAL-ROTATIONAL

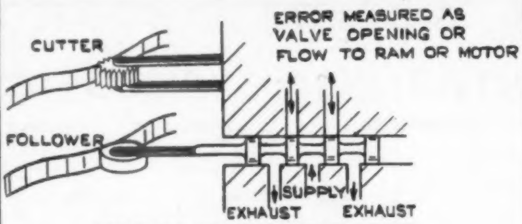


FIG. 4 HYDRAULIC ELEMENT FOR ERROR MEASUREMENT.

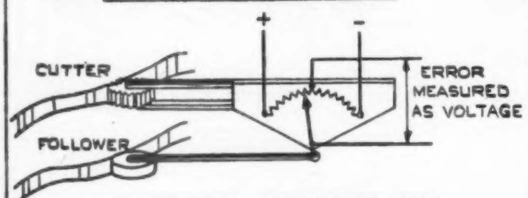


FIG. 5. ELECTRICAL ELEMENT FOR ERROR MEASUREMENT

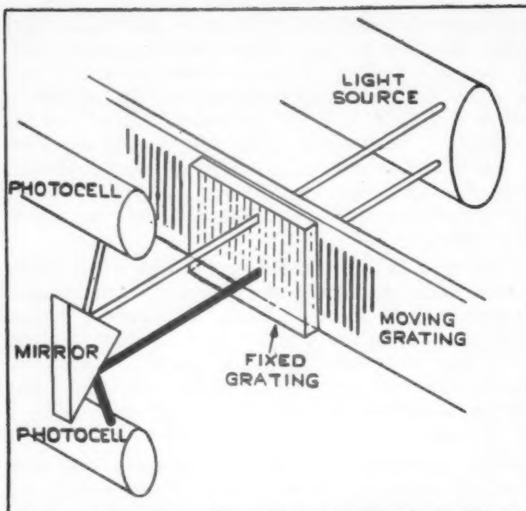


FIG. 6. OPTICAL GRATING MEASURING SYSTEM.

In the electrical example in Fig. 5, the error appears as a D.C. voltage.

Synchros (Magslips) have been extensively used for remote position controls. By use of these, an A.C. voltage is developed proportional to the relative angular displacement of two remote positioned shafts, and by phase discrimination of the carrier we can tell whether the error is positive or negative.

Other methods are being used employing digital or counting methods, each unit or pulse representing a movement of, say, .0005″. Perhaps the most commonly used digital position control is the Automatic Telephone. Its form is, of course, unsuitable for machine positional control (and in addition we would have to be assured that there would be no "wrong numbers").

In machine tool work these digital methods employ an optical system of position measurement. One method, shown in Fig. 6, (Ferranti) is based on the interference pattern produced by two finely ruled gratings when there is a slight angle between the two rulings. One length of grating is attached to the moving part of the work, whilst another short length is fixed to the stationary part. The grating, therefore, slides across the short one with the two surfaces almost in contact. A parallel beam of light is projected through the combination and when there is relative movement, the interference effect modulates the intensity of the beam. One complete cycle of variation in intensity occurs for a movement equal to the pitch of the gratings and, from this, it is possible to obtain two discrete electrical pulses per grating line. With gratings ruled with 5,000 lines per inch, one pulse is produced every ten thousandth of an inch. By arranging two photocells to pick up different phases of light variation, the direction of movement of the table is discriminated.

In this method only displacement is measured, i.e., the table position is held as a number in a register to or from which impulses are added or subtracted when the slide moves to the right or to the left.

A second method (Fig. 7) registers the actual position of the table from a datum point (Mullard). Briefly this method combines an accurate coarse scale with optical interpolation. The coarse scale takes the form of a cut-away buttress thread or saw, each tooth of which is very accurately manufactured to have radial surfaces spaced .1″ apart to an accuracy of .00005″. This rod is fixed to the moving part of the machine and is made of hardened steel with the same coefficient of expansion as the machine. The interpolating scale has 1,000 equidistant vertical opaque bars alternating with transparent bars of the same width. This scale is focussed optically to fit exactly the .1″ spacing. The number of bars visible from the radial edge of the saw-tooth determines the position within the coarse intervals.

In both these optical methods, the error in position is obtained by comparing pulses transmitted according to the desired position with pulses transmitted from the displacement measuring system. For this operation a Dekatron tube may be used. By reversing the connections to the guide electrodes after the required dimension has been set up, the pulses from the displacement measuring system cause the glow to move anticlockwise, resulting in a subtraction of the two dimensions. The position of the glow indicates the error and can be used to control the position of the table.

Amplifiers

It may safely be said that without power amplification, feedback is impossible. By power amplification

is meant the controlling of a supply of power by means of a small amount of power in such a way that a large power copy of the small input power is available at the output. Thus an amplifier may be represented by a box (Fig. 8) with two inputs and one output. Ignoring the proportion of the supply power which is wasted in heating the box (though this may often be sufficient to cause the box designer some headaches) it may be said that the difference between the controlled power and the controlling power is obtained in the box from the supply power.

The controlled power was said to be a copy of the controlling power, but this is only true within limits. The output power cannot exceed the available supply power and before the limit is reached the output usually ceases to be proportional, the output being smaller than the proportional amount. When this occurs the amplifier is said to be saturated.

Again, the time required for the amplifier to respond will modify the copy of the input. In general it may be said that the higher the available controlled power, the slower the response of the amplifier. An input with very rapid change will not be reproduced accurately at the output.

(a) *Electronic Amplifiers*

Thermionic or valve (hard vacuum) amplifiers are common in servo control systems. They provide a convenient and easily controlled method of amplification. They have a very rapid response, which means that they do not contribute to the dynamic lags in the servo system which limit servo accuracy. A well-developed design procedure is available as a result of their use in other applications. Their principal disadvantage is the small power output which can be obtained from them, so that in large systems they must be used in conjunction with some other form of power amplification which is capable of supplying the larger output power.

Their circuitry can be very easily adjusted to "tune" the system for optimum results.

The low power output restriction may be raised at the expense of rapid response by the use of thyratron or gas-filled valves. These are normally supplied with power from an A.C. source ; commonly 50 c.p.s. mains, which places a limit on speed of response if excessive movement at the supply frequency is to be avoided. The thyratron may also be used in conjunction with other forms of power amplification.

An amplifier which is relatively new, but which may find big use in the future, is the transistor or germanium triode. The principal advantages of the transistor are its small size and low power requirements. At present its output power is restricted to a much lower value than is the valve amplifier. Design techniques for transistor amplifiers for servo work would be rather similar to those for valve amplifiers. Transistors may find applications for driving small servos in analogue computers.

(b) *Magnetic Amplifiers*

Another form of power amplifier is the saturable reactor, of which one form is known as the magnetic amplifier. Although the operational principle has been known for nearly 40 years, it is only comparatively recently that improvements in magnetic materials made the efficiency of these devices sufficiently high to be practicable. They were developed in Sweden and Germany, and were used quite extensively in German gun fire control, in stabilisers, automatic pilots and regulating systems during the Second World War. The servo control in the V.2 Rocket was by magnetic amplifier. These amplifiers have a long time lag of the order of hundredths or even tenths of a second, as a result of the high inductance of the control winding and they must be used in conjunction with metal rectifiers

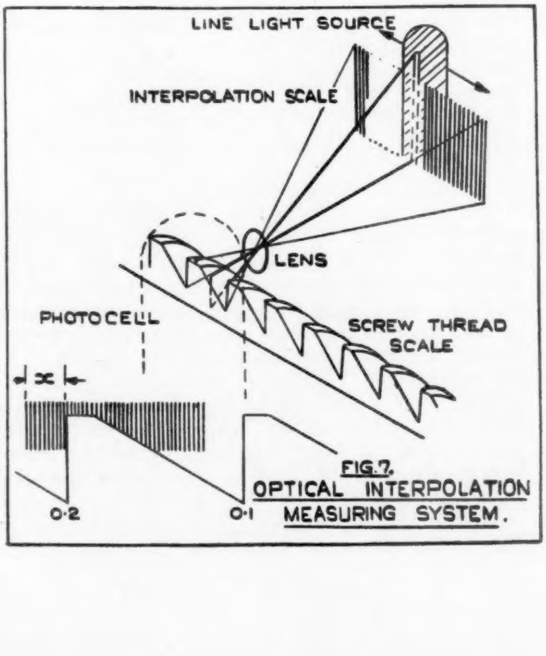


FIG. 7. OPTICAL INTERPOLATION MEASURING SYSTEM.

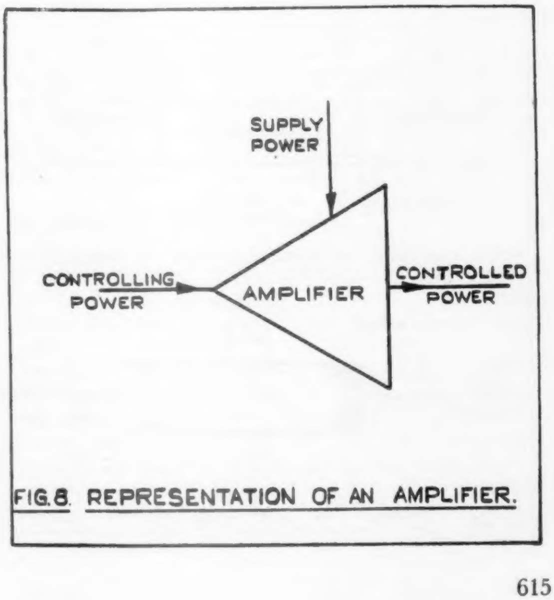


FIG. 8. REPRESENTATION OF AN AMPLIFIER.

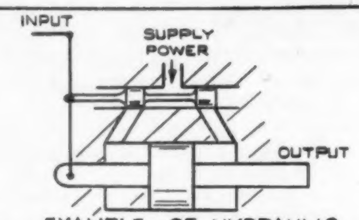


FIG. 9. EXAMPLE OF HYDRAULIC AMPLIFIER — RECIPROCATING.

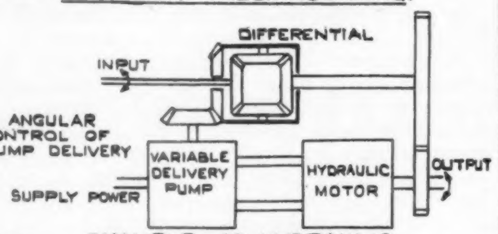


FIG. 10. EXAMPLE OF HYDRAULIC AMPLIFIER — ROTATIONAL.

if cascade amplification is to be used. Although these units are generally made with relatively small power outputs, there is no real reason why large outputs may not be obtained from specially designed units.

(c) *Electrical Amplifiers*

For larger power outputs, rotary amplifiers are often used. The simplest of these is the Ward-Leonard set, in which a motor drives a generator at constant speed. The input signal is fed to the generator field while the supply power comes from the driving motor. The time lag here is caused by the inductance of the generator field, which limits the rate of change of the input signal current.

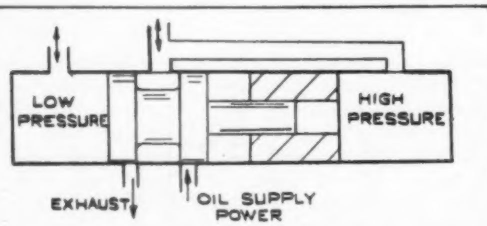


FIG. 11. EXAMPLE OF AMPLIFICATION OF PRESSURE.

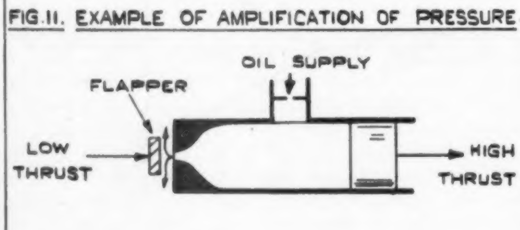


FIG. 12 EXAMPLE OF AMPLIFICATION OF THRUST.

Refinements of this principle are the metadyne and the amplidyne (about 1940.) By means of short circuited brushes these produce in a single unit the effect of two stages of Ward-Leonard amplification. The metadyne has inherent negative feedback which reduces the time lag and has a more rapid response than a single equivalent Ward-Leonard set. The amplidyne, by means of compensating windings cancels out this feedback, and thus has a higher amplification with a greater time lag. Both units must be driven by a motor which provides the supply power.

(d) *Mechanical Amplifier*

The torque amplifier is an example of a purely mechanical amplifier. In this device, the increased power is transmitted from the supply power to the output shaft by means of steel bands round a pulley.

(e) *Hydraulic Amplifiers*

The hydraulic amplifier usually comprises a valve and ram (Fig. 9). Displacement of the valve causes movement of the ram, which in turn recentres the valve. This method of recentring the valve can take many forms and a rotating version is possible where the valve is replaced by a variable delivery pump and the ram by a hydraulic motor (Fig. 10). In these cases, although friction and backlash may be present, lost motion on reversing can be eliminated by dithering the valve. Hydraulic pressure or thrust can be amplified by methods depicted in Figs. 11 and 12.

In Fig. 11, the ratio of increase in pressure is determined by the ratio of piston areas and the increased power is supplied by the oil supply to the valve.

In Fig. 12, the pressure in the chamber is varied by slight movements of the "flapper" at the nozzle. The ratio of the thrusts is roughly proportional to the piston and nozzle areas.

Instability

If the servomechanism is not carefully designed and manufactured, the tool, etc., might not take up the required position and remain there stationary, but may oscillate or hunt about this position. Or alternatively, if the tool is required to move at constant speed, it may move instead at a varying speed.

(a) *Mechanical Considerations*

The position taken up by the table of a milling machine depends upon the mechanical transmission from the motor and the stiction of the table. With a fully loaded table, the backlash between the leadscrew and nut might be in the region of one hundredth of an inch and the leadscrew may be stretched or compressed a further five thousandths of an inch. To ensure that the table takes up exactly the correct position, the sensing device for the position of the table is attached to the table and measures the position directly. When running into the final setting position the table speed falls so low that stiction takes charge and the table may stop a "thou" or so short or overrun by this amount. The measuring system detects this error and causes the control system to

build up motor torque to restart the table. Shafts twist, keys yield, gear teeth bend and leadscrews stretch until a torque is transmitted to overcome the stiction. As soon as motion starts the resistance falls and the energy stored in the deformations cause the table to leap forward, causing overshoot. This process may then be repeated.

To overcome this trouble it is important that backlash be kept to a minimum, friction be kept to a minimum, and the stiffness of all driving parts be kept as high as possible. The use of backlash loaded recirculating ball nuts has been of considerable assistance in achieving these requirements.

For extreme accuracy it may be necessary always to make the final approach from one direction irrespective of the initial approach.

(b) *Consideration According to the Order of the Servomechanism*

In a system where all that is required is that the tool or table moves to a predetermined position and remains there stationary, a control which embodies a single integration is ideal.

With this form of control the velocity of the motor movement is proportional to the error, and it follows that there will always be an error proportional to the velocity of the motor. In such a hydraulic control system, the rate of flow of oil to the hydraulic motor is metered by either a valve or a variable delivery pump. In the corresponding electrical control system the voltage across the motor armature is fed from a low impedance source.

These are first order servomechanisms and provided that backlash and friction are kept to a minimum and the stiffness of the driving parts kept high, a high degree of accuracy is readily possible.

However, if the tool or table is moving during the machining, a control which has an error proportional to velocity may not be acceptable. This problem can be tackled in two ways. Firstly, a first order servomechanism is employed but an additional signal is fed from the command proportional to the velocity of the command. It can be so arranged that this additional signal imparts a velocity to the output equal to velocity of the command and the feedback loop has then to cancel only the small errors of instability. Alternatively, a second order servomechanism can be employed, the motor torque of which is basically proportional to the error and has negligible error due to velocity. These servomechanisms are inherently unstable unless some form of phase advance or anticipation is incorporated in the control.

Anticipation in Continuous Following

A "second order" servo is one which has no velocity error, and for continuous following is therefore more accurate than a first order system. Unfortunately, the second order system is liable to serious overshoot and instability.

Consider a second order servo which is running into line. As it approaches the point at which it should come to rest, the error decreases (Fig. 13). But the second order servo drive produces a torque

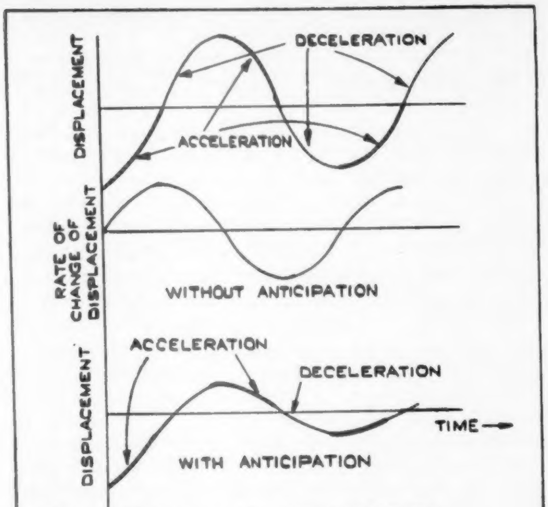


FIG.13. EFFECT OF ANTICIPATION.

proportional to error, so that at the lining up point it has zero acceleration, but a large velocity which carries it over to the other side. Another error is produced which now decelerates the servo until it stops somewhere off its final position. There is now an error which accelerates it back towards the lining up point where it again overshoots, and the process is repeated. If the system is damped sufficiently the swings decrease in amplitude until the system comes to rest at the lining up point. Otherwise, the swings increase in amplitude and the system is said to be unstable.

This state of affairs can be eliminated by what is known as anticipation. If the system is arranged so that a decelerating torque comes into play before the servo reaches its lining up point, the overshoot can be reduced.

This is commonly done by differentiating the error signal to produce a signal which is proportional to the rate of change of error. This is mixed in with the error signal in the amplifier in such a direction as to slow down the servo as it is approaching the lining up position. Thus the overshoots are considerably reduced, and the system is "stabilised".

Advantages of Positional Control

What is the point of adding this positional control to machine tools? Is the additional expenditure on the conversion of existing equipment or on new positionally controlled equipment going to be worth while?

So far as the simple addition of control by itself to a machine tool is concerned, where the initial control comes from the workman who sets up the job, the answer would depend very much on the parts being made. In producing a plate with a large number of accurately placed holes, a positionally controlled drilling machine which could be operated by setting up "map" references to the positions of the holes by

turning knobs to the right numbers would probably be much quicker than conventional methods ; but in making relatively simple work pieces, the additional expense would probably be unjustified.

Positional control has been used for some time now in copying machines where the template has been accurately machined in the tool room, and is fitted to a machine which copies it. The contours of the template are traced by a follower which operates the cutting tool on the machine through a servo system.

However, once a machine tool is positionally controlled, it is possible to derive the controlling signal from a punched card or punched tape through a computer which translates the static information on the card into a continuous signal which controls the position of the blank, under say, a milling cutter, so that a complete item is produced to accurate limits in a very small fraction of the time that would be required for a skilled workman to produce the same work. An example quoted by Ferranti for one piece of work gave two hours for the computer-controlled machine, including programming the computer, against one week for a skilled workman.

For short run items, especially where these are produced in batches at infrequent intervals, this method could show substantial saving over conventional methods, and one manufacturer in this field (Ferranti) is developing a computer-controlled system of this type with an eye on the aircraft industry, where short run productions of complicated items are common, and where this method is likely to have a big future. Other productions where this method will show big savings are waveguide passages in two halves of a solid block and dies for punching and die casting.

Acknowledgments

The Authors are indebted to Messrs. Vickers-Armstrongs (Engineers) Ltd., for encouragement in the preparation of this Paper and to Mr. W. Learmonth in particular for his guidance and helpful suggestions.

"THE IMPACT OF AUTOMATION ON SOCIETY"

(CONCLUDED FROM PAGE 611)

There are a number of implications arising from the suggestions made above :

1. The present Trade Union structure, for example, is related to differences in skills and products, which will become less and less relevant as labour becomes more and more of an indirect, overhead, factor. Some general procedure will have to be laid down for the solution of demarcation and other problems. One possible development is of local federations of Trades Unions with powers to arrive at agreements with individual firms. The Trade Union movement cannot go on leaving the lead in the hands of semi-independent bodies like Trades Councils and shop stewards committees.

2. Problems are also likely to arise from the appearance of new higher, or multiple, skilled workers. Fitting these into the present structure of Trade Unionism and wage differentials will add more anomalies and tensions to both. One difficulty may be the rise of a worker élite, commanding the sort of pay extras now the perquisite, among qualified engineers, of electronics people.

3. Certainly the most serious consequences of automation will be felt among those sectors of industry — and labour — which are *not* involved in the development and application of the new devices.

4. We are in for a period of considerable structural change in the social organisation of industry. There are now very sizeable anomalies between the conduct we take for granted within a factory and what obtains outside it. There are types of conduct tolerated and even approved between people during working hours which would be looked on as outrageous or pathological outside. Somehow or other the system we live in has to be adjusted so that there is less discrepancy between the two. This adjustment will not be brought about by the introduction of Christian naming and asking after the health of the missus, by slick little social devices like canteen committees, but must involve some much more fundamental reorganisation of the roles of people at work, and a recasting of the institutional structure of the workplace.

ULTRASONIC TECHNIQUES IN INDUSTRIAL CLEANING*

by Dr. W. McCRACKEN,

Director of Research, Detrex Corporation.

FOR the past several years, the use of power ultrasonics in the fields of industrial application has been unduly exaggerated. Any proposed application, or any scientist's invention or dream which was associated with ultrasonics, has secured over-optimistic publicity, and encouraged some unwise attempts to utilise ultrasonic energy. Wide areas of research still remain, looking to development of practical and useful ultrasonic processes.

The ultrasonic industrial cleaning process is one such process that has successfully emerged out of several years of applied research. Practical, efficient ultrasonic cleaning units are now available, and in use on high-rate production lines. In order to understand more fully the part this technique plays in industrial cleaning applications, it is desirable briefly to review its development.

As long as 4,000 years ago, noble metals were being plated on base metals. Electrolytic plating as we know it today certainly was not used at that time ; therefore, the plate must have been put on by some sort of a leaf process or a process whereby the article to be plated was immersed in a molten bath. Whatever the process, it was necessary that the metal be clean. We can only assume that this metal was cleaned by hand scrubbing methods of some type using perhaps abrasives, wood ashes, organic matter, etc.

Soap as a cleaning medium is fairly old — just how old seems to be somewhat of a mystery. However, a well-equipped soap factory was uncovered in the ruins of Pompeii. Soap was used in Spain and Italy in the eighth century ; it had gained popularity in France in the twelfth century, and was being used in England in the early fifteenth century. The soap-making industry became so popular in England that the government saw a good chance to make some money and heavily taxed it from 1622 to 1854. (1) In all probability, soap was widely used during this period for industrial cleaning requirements -- whatever they may have been.

The discovery of the soda process by Le Blanc in 1791 probably influenced industrial cleaning techniques. By 1820 soap was being made from soda and the use of wood ashes for this purpose began to decline. By this time we were well into the so-called industrial revolution ; industrial cleaning methods must have been used extensively and probably soda ash played an important role.

The first recorded technical interest in metal cleaning and its evaluation occurred in Germany in 1842. (2) Ludwig Moser published a technical paper indicating that he used the water break test in determining cleanliness. He observed that metal surfaces cleaned with alcohol or ether would permit the spreading of water droplets over the entire surface although, prior to cleaning, the water film would not adhere to the surface.

As late as the twentieth century hand scrubbing and boil tanks using soap were the rule rather than the exception in the cleaning industry.

After 1900 the industry developed new cleaning chemicals and cleaning techniques for industrial use. Alkaline electrolytic cleaning techniques were developed ; certain types of solvents gained favour as cleaning media, and mechanical equipment, such as washing machines of both the spray and paddle wheel type, were developed. Cleaning compounds were formulated for specific types of cleaning jobs. Such equipment and chemicals were widely used and had been highly developed by 1930. From 1930 to 1940, solvent degreasing, using trichlorethylene, came into its own as a leading industrial cleaning process. The high alkaline silicates, synthetic surface active agents, and higher phosphates became available for better alkaline cleaner formulations for specific cleaning jobs. During this period the emulsion-type cleaners were developed and are widely recognized in the industry today.

During the decade of 1940 to 1950 the trend was more towards better equipment, methods, and material handling. Few new chemicals were used ; research was focused on alkaline and emulsion-type compounds. In most recent years, very frequent advances have been made, and the application of power ultrasonics to industrial cleaning techniques is one of the major advances.

Impurities Encountered in Industrial Cleaning

To understand the application of ultrasonics to

* Presented at the 22nd Annual Meeting of the American Society of Tool Engineers, and reproduced by kind permission of the Society.

industrial cleaning, it is necessary to review the types of soil usually found on metal. In general, soil can be classified into two groups:

1. Oxides or similar metallic compounds commonly referred to as rust, scale or tarnish.
2. Greases and oils, or grinding, polishing, buffing and drawing compounds and other organic or inorganic substances, including the finely divided adherent material commonly known as smut.

The first group of impurities are usually a part of the metal itself and are removed by either subjecting the metal part to a chemical treatment which attacks and dissolves the impurity (for instance, pickling to remove oxides), or by physically removing the objectionable residues by mechanical means such as blasting or tumbling.

This discussion is limited to those soils which fall into the second category. Modern cleaning techniques have been fairly successful in removing most types of soils except smut and related materials. These materials are finely divided residues combined with microscopic base metal particles that remain on the surface of a cold worked metallic part after the oils and greases have been removed. These materials are difficult to remove, and in many cases we have been forced to use expensive hand cleaning or cleaning with ultrasonics.

Some terminology definitions are:

1. *Ultrasonic energy* is sound energy which has a frequency above the audible range. The limit of audibility to the average person is approximately 20 kilocycles per second. We are then talking about frequencies which may range from 20,000 cycles to 1 megacycle (1,000,000 cycles per second) as being perhaps the practical limitation of ultrasonics to industrial cleaning problems.
2. *Transducer,* when referred to in this discussion, is a device which transforms electrical energy to mechanical energy which produces compressional waves in the surrounding medium.
3. *R. F.* (*Radio-Frequency*) *Generator* is an electronic device capable of changing the frequency of electric current from, say, 60 cycles per second to many thousands of cycles per second — in this particular case 400,000.
4. *Piezoelectric Transducer.* A device using certain naturally occurring crystals which have the property of changing dimensions and vibrating when an alternating voltage is applied to it. Thus, electrical energy is transformed into mechanical energy in the form of sound waves.
5. *Magneto-strictive Transducer.* A device having a bar or a stack of laminations of suitable ferromagnetic material which, when placed with its length parallel to an alternating magnetic field, produces compressional waves in the surrounding medium.
6. *Electro-strictive Method.* This method differs from the piezoelectric in that a polycrystalline material alternately changes dimensions when an alternating electric current flows through it, causing the electro-strictive effect. Representative of the electro-strictive class is barium titanate which is used as the transducing material.
7. *Curie Point.* The temperature at which a transducing material will depolarize and cease to function as a transducer.

Ultrasonic energy can be produced practically for cleaning applications by using any one of the above mentioned transducing methods: piezoelectric, magneto-strictive or electro-strictive. It is not the purpose of this Paper to give a detailed story of all the forms of ultrasonic transducers. Textbooks (3, 4, 5, 6, 7) will give this information, but all three above methods of transducing electrical energy to sound energy have been used to some degree in cleaning processes. The method which seems best for continuous production line cleaning appears to be the barium titanate, with perhaps the magneto-strictive method running second. This classification is made advisedly, since the technique is very new and little is known about how to use ultrasonic power to its greatest advantage.

The electro-strictive method using barium titanate is the leading technique at the present time. The reasons that the electro-strictive method using barium titanate as a transducer appears to have merit over other types of transducing methods in the application under discussion is that (a) barium titanate is a ceramic and can be cast into various shapes so that the sound energy can be focused on a particular area; (8) after casting and firing, the ceramic can then be polarized to give it electro-strictive properties. (9, 10) This means that the total energy from the surface of a transducer can be utilised after it is concentrated to a high energy density; (b) the impedance is quite low, which allows the unit to operate at comparatively low voltages. For instance, to irradiate an aqueous solution with an ultrasonic intensity of 1 watt per square centimetre and at a frequency of 100 kc, the voltage necessary for a transducer made of quartz crystals would be 10,000 volts, whereas the same result could be achieved by a ceramic transducer with only 100 volts. (11) This low voltage allows for simple connections to remotely located RF generators. The transducer may also be placed directly in non-polar cleaning fluids, such as trichlorethylene, without short circuiting it, thus eliminating the necessity of using inefficient diaphragms or acoustic windows.

Electro-Strictive Effect

The piezoelectric or electro-strictive effect is best shown graphically (Fig. 1). As shown, the effect is of course exaggerated, but Fig. 1 does show what happens at the rate of, say, 400,000 times per second when barium titanate transducers approximately $\frac{1}{4}''$ thick, are exposed to current alternating at a frequency of 400,000 cycles. View (1) illustrates the size of the transducer before applying the voltage. Views (2) and (3) show exaggerated views after applying voltages of opposite polarity.

Fig. 2 illustrates the difference between a transducer which is so designed that the energy is focused, and a flat transducer which is so designed that the sound energy flows from its surface in parallel waves. It is easy to see that with the curved or trough type transducer, all of the energy emanating from the concave surface can be focused in one general area. For industrial cleaning applications, a preferred type of focusing transducer is one which concentrates the energy in a straight line.

Fig. 3 shows diagrammatically a transducer made of barium titanate which is of the shape preferred for many industrial cleaning applications. Both the concave and the convex surface of this transducer are silvered with a silver leaf which acts as the electrodes. Electrical connections are made to each side and the voltage is applied across the transducer between the silvered surfaces. The transducer will then vibrate in its thickness mode, and the acoustical energy emanating from the concave surface will be concentrated at a line above the transducer.

Fig. 4 demonstrates the relative size of a transducer currently used widely in industrial cleaning equipment. This transducer is somewhat longer than the fountain pen, being approximately 6" long and about 3" diameter. As many of these transducers can be coupled together as are required to do a given job.

Transducers may be placed below the object to be cleaned to direct the energy upwards or above the object so that the energy is beamed downwards ; or they may be placed standing on end along the sides of a cleaning chamber. Any combination of the above positions may be used. Transducers, when coupled, may be wired in series or in series parallel. The impedance and average frequency of the transducer train is matched with the RF generator supplying the power.

Generating Equipment

In the case of the barium titanate transducers which are now widely used, a RF generator of approximately 400 kcs is required. The capacity of these generators may vary from ½ kW to 10 or more kW, depending upon the cleaning application.

Fig. 5 shows the front view of a ¾ kW generator which is now being used on a production line. You will note that the electrical leads from the RF generator to the ultrasonic cleaning unit are shielded so that radio frequency cannot interfere with other types of equipment operating in the area, such as communication equipment. The leads may be copper bars, copper tubing or coaxial cable. This particular installation has leads constructed of copper bars which are insulated with plexiglass and then shielded.

Applying Ultrasonic Energy to Industrial Cleaning

Fig. 6 shows the violent agitation which occurs in a cleaning medium when an uninsulated barium titanate trough type transducer is placed in the non-polar solution (trichlorethylene) and activated by a RF generator which is matched to the resonant frequency of the transducer.

To obtain the best results and maximum efficiency

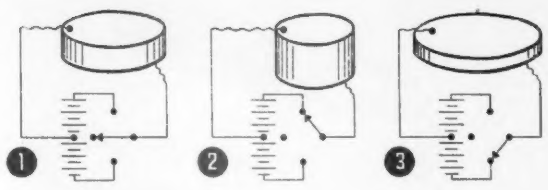


Fig. 1. Piezoelectric behaviour (exaggerated) of ceramic material: (1) before applying voltage; (2 and 3) after applying voltages of either polarity.

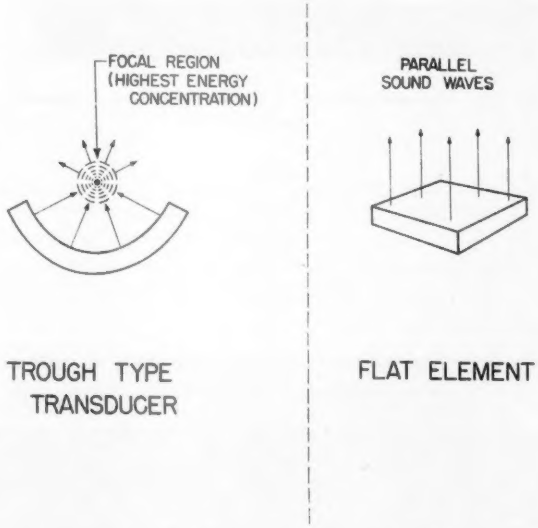


Fig. 2. Comparison of energy focussing.

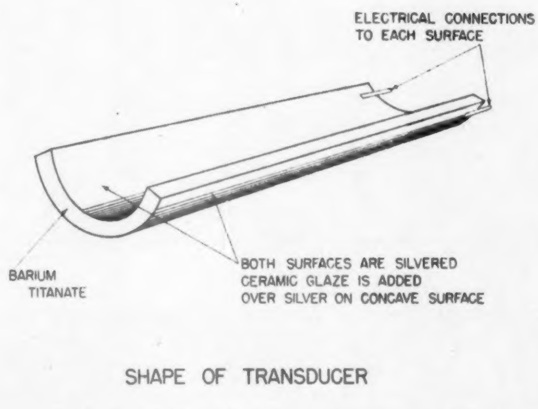


Fig. 3. Design of barium titanate transducer.

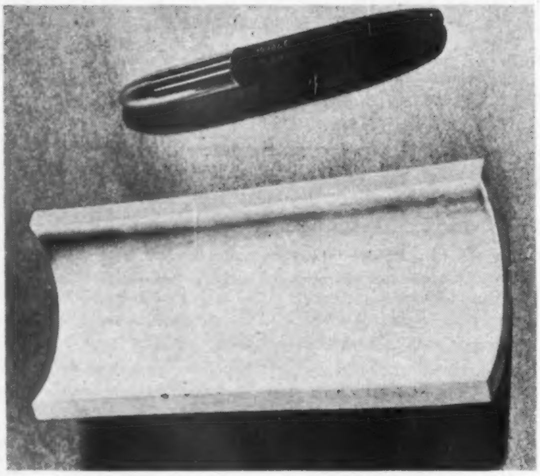
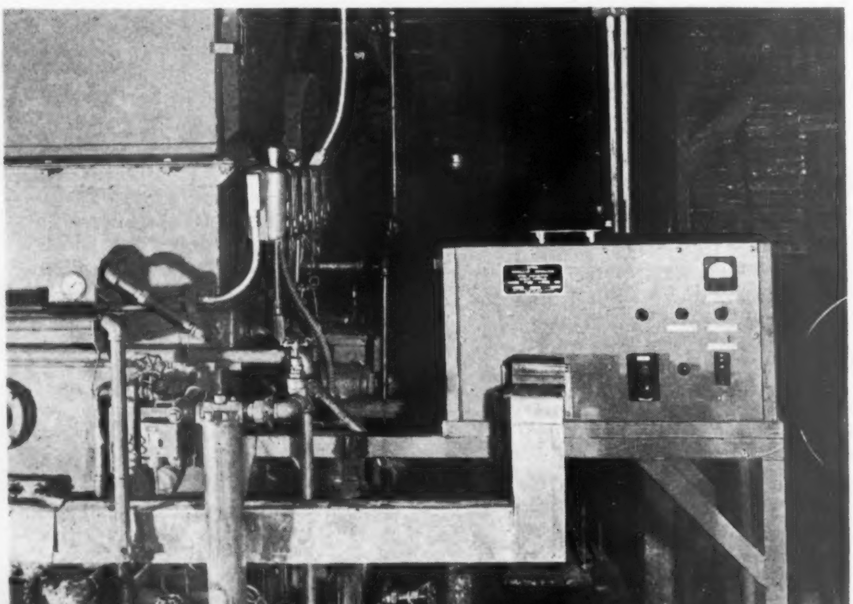


Fig. 4. Size comparison of a transducer and a fountain pen.

from ultrasonic energy, the technique must be employed as a tool in conjunction with a well designed cleaning process. Where present methods are not adequate, the ultrasonic technique is employed only as an additional process to remove the final traces of objectionable soil still remaining. In other words, the ultrasonic technique should be used as an additional process to attain perfect cleaning. The transducers then operate in a separate cleaning chamber in which the ultrasonic energy will remove the final traces of residue after the gross soil has been removed. The last traces of soil may be removed from the liquid by filtration or other means, so that the work piece being cleaned may be withdrawn from the liquid without fear of redeposition of soil. This type of application lends itself very nicely to the solvent degreasing process.

Fig. 7 diagrammatically shows a solvent degreasing process to which an ultrasonic chamber has been added. The solvent degreaser, as such, may be operated by utilising one of the popular solvent degreasing cycles, such as vapour-spray-rinse, immersion-vapour-rinse, etc. The gross soil is removed during this regular cycle of operation and the final traces of residue are removed as the work piece goes through the ultrasonic chamber. The work piece is always immersed in the liquid in the ultrasonic chamber. The distillate from the boil chamber is condensed at the vapour control zone and is pumped continuously through spray nozzles which flood the work piece as it leaves the ultrasonic chamber. This distillate spray drops into the ultrasonic chamber and continuously flows into the rinse which

Fig. 5. Three kW generator, showing shielding against radio-frequency disturbance.



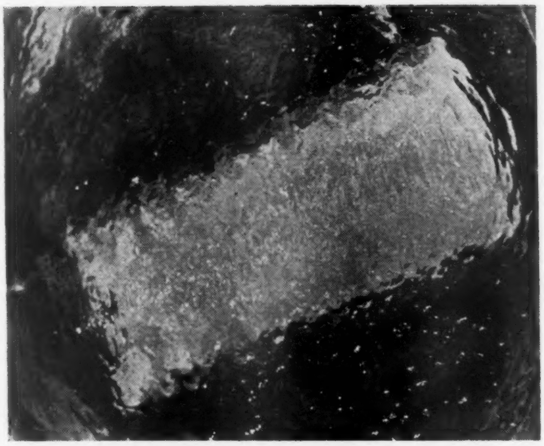
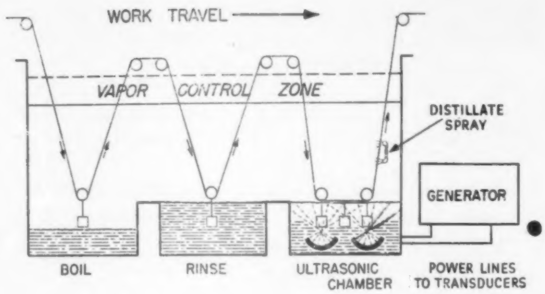


Fig. 6. Agitation occurring in a cleaning medium by ultrasonic energy.



TYPICAL 3-STAGE DEGREASER WITH ULTRASONIC CHAMBER

Fig. 7.

continuously overflows to the boil chamber. The recycled distillate is an aid in keeping the ultrasonic chamber free from soil. In addition, the liquid in the ultrasonic chamber is continuously filtered at a high rate (not shown) which reduces the soil suspended in the ultrasonic chamber to a minimum. If necessary, separate distillation equipment is placed in the system to force additional clean distillate to the ultrasonic chamber. The temperature of the solvent in the ultrasonic chamber is kept at approximately 140°F, which seems to be optimum for cleaning and is sufficiently low to prevent the transducers from reaching the Curie temperature (248°F), at which temperature they would depolarize. The transducers are loaded at four watts per square centimetre.

Fig. 8 illustrates the loading and unloading end of another unit and in some detail the cross-rod conveyor and work fixtures. This machine is operated at a rate of several thousand parts per hour.

Other models of this same type unit are equipped with monorail through type conveyors rather than the cross-rod conveyor. They may be adapted to almost any type of material handling.

Another unit (not shown) is so designed that the RF generator is placed on top of the solvent degreaser. This is a pin-type conveyor and the baskets which contain the work to be cleaned are placed on the pins. A plastic window allows an observer to see the work baskets pass over the transducers.

Fig. 9 shows Magnaflux being literally exploded from a jet engine blade. This blade was treated with Magnaflux and allowed to air dry for a period of several hours. It was then dried in an oven at elevated temperatures for several hours and then allowed to stand at room temperature for two days. At this stage the only method by which all of the residual Magnaflux could be removed was by some physical method such as hand wiping. This blade, however, when exposed to ultrasonic energy in a trichlorethylene bath, was completely cleaned of all residue within a few seconds.

The effectiveness of ultrasonics in cleaning metal parts is shown in Table 1 (overleaf).

Fig. 8. Loading and unloading end of an ultrasonic cleaning unit.

TABLE I. COMPARISON OF TOTAL SOIL CONTENT 16 HYDRAULIC VALVE LIFTER ASSEMBLIES FROM A MODERN V-8 ENGINE

Method of Cleaning	Soil Content per 16 Assemblies, Grams
1. Before cleaning	0.035 to 0.050
2. After 3-stage washer	0.003 to 0.0059
3. Vapour spray degreasing and ultrasonics	0.004

In this particular test, hydraulic valve lifter assemblies, ground and lapped to precision tolerances, were cleaned in groups of sixteen. The tabulated data show that vapour spray degreasing, plus ultrasonics, did a far better cleaning job than the method which was currently being used in the plant at the time the tests were made. After cleaning, these parts were rinsed by forcing a direct spray of filtered and distilled petroleum solvent over the parts with a laboratory syringe. The off-fall was collected in a large evaporating dish, allowed to stand for one hour and then the clear solvent was decanted. The remainder was placed on a watch glass, evaporated to dryness and weighed. This evaluation outlines in a rather positive way the outstanding cleaning abilities of ultrasonics.

Table II shows the results of tests which were made on bearing components. Results from three different processes now in use are shown, and in the last column is shown comparative results using a degreasing cycle plus ultrasonics. This process was being operated in an area without the benefit of air conditioning, therefore, additional tests were run to determine how much soil was picked up from the atmosphere from the time the parts left the ultrasonics cleaning unit until they arrived at the point where the evaluation was being made. A watch glass having the same area as the bearing components and which was thoroughly cleaned was carried with the components from the ultrasonics cleaning process to the evaluation area.

Fig. 9. Magnaflux being "exploded" off a jet engine blade.

TABLE II. NUMBER OF SOIL PARTICLES AFTER CLEANING, USING DIFFERENT METHODS (BEARING COMPONENTS)

Particle Size Dia. in Inches	Other Methods No. 1	Other Methods No. 2	Other Methods No. 3	Immersion, Vapour, Rinse Degreasing and Ultrasonics
Less than 0.001	1,012	1,240	608	196
0.001 – 0.003	204	196	172	44
0.003 – 0.005	8	56	11	8
0.005+	4	15	3	7
Lint fibre	9	21	13	12
Steel	28	22	17	16
Total	1,265	1,550	824	283

Table III shows the results of these tests. It is interesting to note that approximately the same amount of soil was picked up on the watch glass from the atmosphere as was shown on the parts which had been cleaned in the ultrasonic process. We can, therefore, assume that the bearing components as they came from the cleaning process were essentially free from all contamination. After these tests, steps were taken to install the process in an air conditioned area.

In summary, it can be said that the ultrasonic technique can, and is, being used as a powerful tool in the field of industrial cleaning ; that it is best employed as the last stage of a well-designed cleaning process ; that it is adaptable to the process of solvent degreasing using chlorinated hydrocarbon solvents ; that barium titanate transducers are far more adaptable than other types at the present time ; that the ultrasonic technique can, and is, being adapted to production line cleaning ; and lastly, that the best cleaning results in the history of the industry are being obtained by ultrasonics in conjunction with solvent degreasing.

TABLE III. TEST OF WATCH GLASS

Particle Size Dia. in Inches	Test No. 1	Test No. 2
Less than 0.001	150	160
0.001 – 0.003	100	37
0.003 – 0.005	20	11
0.005+	5	6
Lint fibre	4	5
Steel	6	3
Total	285	222

REFERENCES

1. " Americana." Volume 25, page 154.
2. " I. Ueber das Latent Werden des Lichts ", Annalen der Physik und Chemie. Volume 57, No. 9, pages 1 - 34 (1842).
3. E. G. Richardson : " Ultrasonic Physics." New York (1952).
4. P. Vigoureux : " Ultrasonics." New York (1951).
5. L. Bergmann : " Der Ultraschall." 5th edition, Zurich (1949).
6. W. P. Mason : " Piezoelectric Crystals and Their Application to Ultrasonics." New York (1950).
7. E. Hiedemann : " Grandlagen und Ergebrisse der Ultraschall for schumg." Berlin (1949).
8. U.S. Patent No. 2,565,159.
9. U.S. Patent No. 2,486,560.
10. U.S. Patent No. 2,640,165.
11. " Brush Strokes." Volume 3, No. 2, July, 1953, page 3.

INSTITUTION PUBLICATIONS

" The Automatic Factory — What Does It Mean?" Proceedings of the Margate Conference, 1955. Price 30/- from the publishers, E. & F. N. Spon, 23 Henrietta Street, Strand, London, W.C.2.

" Production Control and Related Works Statistics." Report of the Joint Committee of the Institute of Cost and Works Accountants and the Institution of Production Engineers. Price 5/- from Gee & Co. (Publishers) Ltd., 27/28 Basinghall Street, London, E.C.2.

" Material Utilisation in the Metal Working Industries." Report of the Material Utilisation Sub-Committee of the Institution of Production Engineers. Price 5/4d. from the Publications Dept., 10 Chesterfield Street, London, W.1.

GLASS FIBRES AND

THEIR USE IN REINFORCED PLASTICS

by A. R. HENNING, B.A.,

Fibreglass Ltd., St. Helens.

Presented to the Oxford Section of the Institution, 19th January, 1954.

REINFORCED plastics has been claimed to be an industry in its own right and not merely a branch of the traditional plastics industry. This claim may be justified perhaps by pointing to the different moulding methods used, to the equipment made necessary, or to the market for which the products are made, but fundamentally it is in the properties of the mouldings that one finds the real justification. Polyester, methyl methacrylate, polystyrene and phenol formaldehyde mouldings or castings have tensile strengths up to 11,000 p.s.i., Young's moduli of up to 800,000 p.s.i. and for this degree of rigidity, Izod impact strengths of not greater than 0.5 ft. lb. They are in general notch sensitive and have poor dimensional stability compared to metals.

Reinforced plastics are far from being a novelty. That they should be so regarded by many people is evidence of the significant all-round increase in mechanical properties which the combination of glass fibres and certain plastics has effected. By their use, the values just quoted may be quadrupled for tensile strength and stiffness and multiplied 40 times for impact resistance. They have, in fact, made possible the production of large thin-walled structures light in weight and highly resistant to mechanical damage. Methods for forming such structures have been borrowed from the plywood industry, the felt hat manufacturers and the pulp moulders, as well as the orthodox plastics industry. Resin formulations have been developed or modified especially for use with these methods and prepared in suitable forms for impregnating fibrous reinforcement.

Historically, the applications for the combination of glass fibres and low pressure resins, particularly the polyesters, have been radomes and a host of other aircraft parts on acount of the high strength/weight ratio combined with good electrical properties, bullet-proof armour, boats, boxes, trays, washing machine tubs, chairs, suitcases, roof lights, oil, water and chemical tanks and pipes, and now sports car bodies, lorry cabs, and almost complete 'bus bodies. There have, of course, been many less spectacular uses, but this is a selection of items requiring shell strength in which the properties of the material have been fully utilised.

The essence of reinforcement of plastics lies in the efficient transfer of stress by the low strength plastic continuum to the high strength fibre, rod or plate. The fibrous form is a very convenient one, since a large surface to volume ratio is offered and allows intimate contact with the plastic material at high reinforcement to plastic ratios. Glass fibres have a tensile strength in the region of 100 tons/sq. inch, and a modulus of elasticity equal to aluminium, with a specific gravity of only 2.57. The tensile strength is greatly in excess of " massive " glass, which averages only 6,000 p.s.i. The reasons for this phenomenal increase are not well established, but factors involved seem to be the drawing out of surface flaws with possibly a degree of molecular orientation, together with toughening which undoubtedly takes place during the rapid cooling when the filament is drawn. In common with massive glass, and unlike cellulosic materials, the fibres are durable and have a temperature resistance well above that of plastics they might be required to reinforce. As the fibres are solid, there is low moisture pick-up which, coupled with the inherent low thermal expansion, ensures good dimensional stability. Since they are man-made and

continuous filaments can be drawn, their physical and chemical characteristics are controllable, and orientation to yield particular strength characteristics in laminates is readily achieved. The drawing of continuous filaments also simplifies the uniform arrangement of fibres in bundles or strands. It is found, as might be expected, that reinforcement with monofibres yields only brittle, low strength laminates. When bundles of parallel fibres are used, stresses which would cripple single fibres can be transmitted by the resin and shared between all in the bundle. The more efficient packing of fibres in this form itself leads to higher strengths, on account of the higher reinforcement content of the laminates.

On the debit side, although these fibres will not rot and are durable compared to most organic materials, they are not readily wetted by most resins and the bond deteriorates under moist conditions unless special precautions are taken.

Price is higher than many natural fibres but this is largely irrelevant, since a quite different set of properties is achieved by their use. From a strategic point of view, and this is important in view of their wide use for Service requirements, their production is in no danger at all ; the raw materials are plentiful in this country and equipment for producing them can be rapidly expanded. Strength comparison with other fibres (Tables 1 and 2) is favourable and this coupled with the considerations outlined has led to their preponderance as reinforcement for structural plastics.

Production

Production of Glass

Silica is the basis of all fibre-forming glasses, but it is necessary to modify it in order to draw continuous filament having the balance of properties necessary for plastic reinforcement. Alumina, lime, borax and smaller amounts of other chemicals may be added to lower the melting temperature, improve chemical resistance, reduce tendency to crystallisation and generally give a glass which draws satisfactorily to uniform high strength fibre. The granular materials are mixed together and fused to emerge as a stream from the melting tank and be cut into 'gobs' for rolling into marbles. In the form of marbles they can conveniently be fed into the fibre-forming equipment.

Production of Glass Filament

Glass may be drawn into both continuous and discontinuous filament by a variety of methods. One widely used method is as follows. Marbles of carefully controlled composition are melted in an electrically-heated crucible carrying in its base a number of dies. The crucible used for production of continuous filament normally carries 204 dies from which the glass is drawn by means of a high-speed winding unit. The basic filaments are gathered together at a pad where a size provides both lubrication and the means of holding the filaments together in strand form. More will be said of the various sizes later, but it should be noted that filaments of a hard and abrasive

Table I.

PHYSICAL PROPERTIES OF GLASS FILAMENT

Tensile strength p.s.i.	180,000 - 250,000
Young's modulus p.s.i. ...	10×10^6
Specific gravity	2.57
Thermal conductivity B.Th.U.-inch/sq. ft./hr./°F.	7.0
Thermal coefficient of expansion /°C.	5×10^{-6}
Specific heat Calories/gram./°C. ...	0.20

nature, with a high surface area to volume ratio, are being wound up together at high speed on a package from which they have later to be unwound without damage.

The filament diameter depends upon the furnace temperature, the head of glass, the die diameter, and the winding speed for any given glass composition. Since the flexibility of the filament is a function of its diameter, a limit is set to its increase for any particular purpose but as coarse a filament as possible is used on economic grounds. For most reinforcement products a filament diameter of 0.00034" is at present being used, although finer filament is employed for woven fabrics in many cases. The following Table shows the relationship between the filament diameter and the yarn count. The latter will be seen to be the number of 100 yd. lengths of strand in a pound.

Diameter	No. of filaments	Yds./lb. of strand	Count
.00021"	102	90,000	900's
.00021"	204	45,000	450's
.00028"	204	22,500	225's
.00034"	204	15,000	150's

For filament which is to be twisted and doubled into yarn and then woven into cloth, the size has to be particularly efficient in preventing the fine filaments from abrading each other and usually contains a number of oily constituents in addition to those which hold the filaments together in strand form. Despite a great deal of research, it has so far been found impossible to apply a size which will do this work and at the same time function as an efficient coupling agent between laminating resins and the glass surface.

For filament which is to be used in unwoven form, however, and which is acordingly less subject to abrasion, various sizes have been developed which give adequate lubrication and interfilament adhesion, whilst being compatible with the types of resin which are at present in widest use for low pressure laminating. These sizes are formulated to provide a key to the glass surface—a condition already stated to be highly desirable for efficient stress transfer.

The common starting point for all these reinforcement products is the " cake " of strand as taken from the high-speed winding unit.

COMPARATIVE STRENGTHS OF REINFORCEMENT FIBRES.

Fibre	Tensile Strength $\times 10^{-3}$ p.s.i.	Young's Modulus $E \times 10^{-6}$ p.s.i.	Nature
Glass (Commercial reinforcement)	180-250	10.0	Inorganic Continuous filament.
Asbestos (High grade chrysotile)	216(1)	26.5(1)	Inorganic Short fibres.
Wood fibre (Kraft paper)	approx. 130(1)	10.5(1)	Natural cellulose. Short fibres.
Flax	118(2)	4.0(2)	Natural cellulose. Fibres
Viscose rayon (Stretched)	108	1.27	Synthetic. Continuous filament.
Nylon	72	0.7	Synthetic Continuous filament.
Cotton	68(2)	1.1(2)	Natural cellulose Short fibres.
Viscose rayon	41(2)	1.27(2)	Synthetic Continuous filament.

References:

(1) Gordon, J. E. "On the Present and Potential Efficiency of Structural Plastics". Journal R.Ae.S., Sept. 1952.

(2) Meredith, R. Shirley Institute Memoirs (1944).

Table 2.

Roving

A roving is a number of parallel strands of filament differing from yarn in having no twist. The number of strands is mainly dictated by the end use of the roving; that for use in the flock preform process is normally 60, while 6, 12 and 60 strands may be used for the production of various grades of solid rod stock and pipes. Tensioning difficulties in the winding process impose an upper limit to the number of strands or " ends ", while the decreased poundage per hour from the machine for the smaller number of ends is reflected in the higher price for 6 and 12 end roving.

Chopped Strand Mat

Filament from a number of cakes is passed to a cutter, so that 2" strands fall in random fashion and form a layer of uniform thickness on a conveyor. The mat is sprayed with a binder which is oven-cured before the mat is rolled up. Various mat binders may be used, depending upon the type of laminating resin and on whether heated matched metal dies are to be employed. Uniform binder penetration imposes limitations upon the thickness of mats and those generally available are between 1 and 4 oz/sq. ft. Another type of chopped strand mat which has been produced experimentally in the U.S.A. is held together without the use of a chemical mat binder and can be made in weights up to 10 oz/sq. ft. The chopped strands are randomly distributed on a thin carrier tissue or fabric and the mat is then pierced by hundreds of needles which, by picking up strands from the top and carrying them through to the tissue, provide mechanical bonding. The absence of mat binder means that a wider range of resins can be used without fear of incompatibility, that the bonding of resins to glass is more direct, and that " wetting out " is more rapid. The ease of wetting out probably lessens the likelihood of entrapping air in laminates made from the thicker mats. Mechanical bonding eases the problems of pre-impregnation and, since for a wider range of mouldings single thicknesses can be used, there are lay-up time economies.

By virtue of the random strand orientation, chopped strand mat yields laminates with omni-directional properties. It is not usually possible to get a higher glass content than 35% by weight unless pressure is used, and the strengths of mat laminates are accordingly lower than those made with cloth. It is used principally in the hand lay-up process but, if formed with a binder having a high softening point and not readily soluble in the moulding resin, it may be used for heated matched die moulding. One of the largest uses at present is for translucent sheeting, which may readily be made to the contours of corrugated roofing or have a smaller corrugation or fluting for decorative work. Here the binder should be wetted out by resin and remain in solution, so that a high degree of light transmission can be achieved.

Chopped Strands

For some moulding operations loose chopped strands are required and these may be made either directly from " cakes ", or from roving. Processors frequently use disintegrated preforms or off-cuts of mat. Since it is found that the reinforcement value in polyester resins falls away sharply below a strand length of ½" and it is also difficult to prevent breakdown into basic filament, chopping below this length is unusual, although as low as ¼" strands have been produced and are useful in patching operations. The main use for chopped strands at present is in the dough or ' gunk ' moulding process, where they are mixed with catalysed resin and a high proportion of clay filler to yield a compression moulding compound. Press tools can be made with similar compounds, although lower viscosity is convenient.

Diamond Mat

This is an elongated diamond pattern web of strands made by traversing a suitable number of ends across a revolving drum. The angle the strands make to the longitudinal axis is small and hence the strength is practically all in this direction. The mat is normally used in conjunction with other reinforcements to give increased strength and stiffness in one direction.

Surfacing Mat

This is not really a reinforcement product at all, but a tissue of randomly distributed fibres used to hold a high proportion of resin on the surface of a moulding and thus impart good surface finish.

Woven Fabrics

The strand, which has been made with textile size, is twisted and doubled into yarn machinery which is standard in almost every respect and which imparts twists of 1 - 4 turns/inch in the yarns. Unlike staple textile fibres which require substantial twisting to give a strong yarn, continuous filament glass requires only sufficient to hold strands together and so is able to transmit a high proportion of the fibre strength and stiffness to laminates. Looms again are standard except that care is taken to avoid abrasion at guide eyes and similar points of yarn contact. As far as weaving is concerned, glass yarns differ from other textiles mainly in regard to their hardness, smooth surface and relative lack of flexibility and stretch—these properties affecting the construction of cloths in several ways. The cloths woven as plastic reinforcement are mainly of three types: *plain weave*— i.e., where each thread passes over one thread and under the next; *twill and satin weaves,* where threads float over two or more threads before again pasing under one; *unidirectional weaves,* in which heavy yarns are used. in the warp and relatively light yarns as weft hold them together.

Yarn Crimp

Yarn crimp adversely affects both the tensile and compressive strengths and modulus of elasticity of laminates. When a laminate is stressed in tension, the pressure exerted at the intersection of yarns is increased and, due to their hard and self-abrasive nature, fracture can occur. In flatwise compression,

the deformation of the low modulus resin causes the yarns to be strained in tension and the same thing occurs. In edgewise compression, the yarns lying in the direction of the applied stress are already buckled and the tendency to buckle further is greater than would be the case with less crimped yarns, i.e., the value of Young's modulus is reduced. When a laminate reinforced with crimped yarn is strained in tension, deformation proportional to the crimp occurs before the yarn takes its full share of the load. Measured values of E show a reduction on what is obtained when little crimp is present.

High crimp does, however, have two advantages. Under impact, energy is absorbed before the fibre columns are stressed, although, again due to the hardness of the glass, local crushing may occur under high point loads. The second advantage is that interlaminar adhesion is better than with "smooth" fabrics and depends less upon the bonding strength of the resin. This has been well demonstrated in the case of the laminates made with silicone resins where, to get reasonable machining properties, it is necessary to reinforce with the coarser plain weave cloths.

The smoothness of continuous filament glass yarns leads to weave slippage and sets an upper limit to the openness of a fabric unless special locking weaves are employed, and sets a lower limit to the number of intersections which yarns may make with one another. That weave distortion can occur, particularly with twill and satin weaves, is made use of in forming cloth to double curvature. As the yarns themselves, unless made with high twist, have an extension of only about 3%, weave distortion or straightening out of crimp with, for example, knitted fabric, is the only means of obtaining stretch. With most plain weave cloths, one has to resort to hand tailoring to make them conform to double curvature.

As flexibility of the basic filaments depends upon their diameter, the coarser filament yarns naturally suffer more damage in the twisting and weaving processes than do the finer ones, but cloths woven from yarns made with 150's count filament have on lamination been found to yield tensile strengths not significantly different from those made with 225's count yarn.

The particular uses of the main types of cloth are as follows :-

Square Weaves

These are useful in cases where :-

(a) crimp is needed to give good impact strength ;
(b) crimp is necessary to increase interlaminar strength ;
(c) where porosity, as would be the case with an open weave cloth, is required for ease of impregnation and removal of air.

Satin and Twill Weaves

These are best used

(a) where high strength and modulus of elasticity in directions at right angles are required while weight is kept to a minimum ;
(b) where the weave is required to distort either for deep draws or to mould to double curvature without hand tailoring ;
(c) where high glass content for dimensional stability, etc., is necessary.

Unidirectional Weaves

These should be employed when :-

(a) stress is predominantly in one direction and structural efficiency is of importance ;
(b) stiffness is required mainly in one direction.

In general, cloth is used where the higher strength/weight ratios are required as is the case in aircraft structures, where uniformity of thickness is important, or where the economics of using unwoven reinforcement do not apply. It is also sometimes necessary to use cloth as, for instance, when resins have to be used which are incompatible with existing sizes or mat binders.

Cloth Treatments

It was stated earlier that due to the spinning and weaving operations which the filament has to undergo before becoming cloth, a textile size had to be applied containing various oily constituents which would prevent the resins wetting the glass surface. The importance of maintaining the filaments in bundles or strands was also emphasised. By virtue of its interlocking construction, a cloth can be subjected to treatments capable of removing the 2 - 3% of size, either partially or completely, without disturbing the filament arrangement. These consist in varying degrees of heat treatment or of washing in detergents to remove some or all of the size. Heat treatment to remove as much of the size as possible — usually 0.1% of carbonaceous matter is left — is the most popular since it enables the fabric to be "finished" with a "coupling agent". Some reduction in strength of the fabric is involved, as might be expected if the reasons put forward for the high strength of the fibre compared with "massive" glass are true. To appreciate the desirability of applying a surface treatment, it is necessary to go further into the properties of glass fibres.

Although glass is inorganic, it is not unaffected by water and this becomes apparent when it is drawn into fibres with a high surface area to the volume ratio. The great strength of silica glasses is due mainly to a skeleton of silicon-oxygen linkages, and on exposure to water the hydrogen ions are thought to cause a reduction in the number of these bonds, hence weakening the glass structure. This is purely a surface effect at first, although progressive breakdown of the structure of the glass can take place with some compositions. The effect is obviously highly undesirable and a number of methods have been devised to prevent the surface of the glass coming in contact with appreciable amounts of water when the laminating resins are such that they do not themselves key to the glass. This is particularly the case when, as seems to occur with polyesters, the resins shrink away from the glass and provide capillaries along which water can travel. These methods consist in applying to the desized glass cloth a complex substance which will adhere strongly both to the glass surface and to the laminating resins. It is not proposed to go into much detail, because the chemical

VARIATION OF PHYSICAL PROPERTIES OF POLYESTER LAMINATES WITH TYPE OF REINFORCEMENT.

Property	Rovings	Unidirectional fabric (parallel laminated)	Diamond Mat (parallel laminated)	8-end Satin Weave (square)	Chopped Strand Mat or Flock Preform	Pure Polyester Resin
Tensile strength	120,000	77,000	60,000	40,000	25,000	6,000
Flexural strength p.s.i.	150,000	115,000	80,000	60,000	32 000	13,000
Compressive strength p.s.i.	70,000	70 000	—	35 000	25,000	21,000
Flexural modulus	6×10^6	5×10^6	3.8×10^6	3×10^6	1.7×10^6	0.3×10^6
Izod impact strength (Unnotched) ft.lb./in.	70	55	—	25	20	0.3
Specific gravity	1.9	1.85	1.7	1.75	1.55	1.3
Moisture absorption % (24 hrs. immersion)	0.15	0.25	—	0.3	0.4	0.4
Thermal conductivity B.Th.U-in/sq.ft./hr/°F	3.0	2.5	—	2.0	1.7	1.2
Linear expansion/°C	7×10^{-6}	9×10^{-6}	—	10×10^{-6}	25×10^{-6}	100×10^{-6}
Typical glass content %	70	66	50	62	35	0

NOTE - Strength figures of the same order of magnitude are obtainable using epoxide and low pressure phenolic resins, excepting impact strength which is lower in the case of the latter.

Table 3.

nature of many of these coupling agents or "finishes" is not known for certain and reactions of some of those which have been disclosed are still the subject of speculation. One of these treatments based on methacrylato-chromic chloride is commercially available now and is applied by weavers in England as a standard treatment. Besides protecting the glass fibre surface from the effect of moisture and thus tending to keep up the strength of the laminate under wet conditions, by improving the bond between the resin and the reinforcement it yields better mechanical properties under all conditions than the simple heat treatment. It has the further important effect of facilitating the wetting of the glass by the resin.

Experiments have also been made with various other coupling agents of the organo-silane and siloxane groups, which are claimed to give somewhat superior wet strength retention to that afforded by the chrome complex, but most introduce considerable processing difficulties. The vinyl trichrosilane finish appears simpler chemically than some of the others and well illustrates the principle of a coupling agent. There is no particular reason why polyester resins should adhere to glass and the likelihood of their not doing so is strengthened by the affinity of the nascent glass surface for water. In the case of vinyl trichlorsilane being applied to the hydrated surface, the chlorine reacts readily with the hydroxyl groups to form HC1 and the silicon links up with the oxygen as in the glass structure. Due to the evolution of HC1 gas the processing is rather objectionable and this particular finish has not so far been taken up commercially, although tests in this country have shown it to give a better wet strength retention than the methacrylato chromic chloride.

While discussing treatments, it should perhaps be pointed out that the size which is at present applied to most of the unwoven reinforcements in England

is based upon polyvinyl acetate, which itself has bonds available for linkage with polyester resins, and a proportion of methacrylato chromic chloride is added to key to the glass fibre surface and assist wetting with the resins.

New Developments

(a) *Roving Fabrics*

A recent development is the weaving of heavy fabrics from roving and, if this can be done on a commercial basis using standard reinforcement roving rather than that made with textile size, it should find wide application. Higher tensile strength and modulus is obtainable with such reinforcement since there is no twist in warp or weft, and if reinforcement size is used, desizing with consequent loss of strength is avoided. Although heavy fabrics can be woven, their use alone is restricted by the tendency of such laminates to split along the line of warp or weft and to delaminate when flexed. Their use with chopped strand mat would seem to be the right solution, as this would improve the interlaminar adhesion and impart strength in directions in which the roving cloth is deficient.

(b) *Pre-impregnated Cloth and Mat*

Woven cloths pre-impregnated with phenolic, polyester, epoxide and silicone resins and the chopped strand mat, pre-impregnated with catalysed resins at the "B" stage of cure, have been available in experimental quantities. The low "pull strength" of standard chopped strand mat makes continuous impregnation difficult at present. Pre-impregnated roving fabric has much to offer in regard to economies of lay-up and is becoming popular in U.S.A. It is too early to be dogmatic about the advantages of pre-impregnation but the following points have been made with some justification :-

(i) Its use is less messy and leads to more careful work than with liquid impregnation.

(ii) Since a process depending very largely for its time of execution upon the skill of an operator is eliminated, production line techniques are more feasible.

(iii) A controlled resin content with practically no resin wastage is achieved.

(iv) When the air has been removed from the reinforcing base during the impregnation process, mouldings free from pinholes result.

Disadvantages seem to be :-

(i) The material is expensive compared to cloth and resin prices.

(ii) Both heat and pressure are needed during moulding, although for unfilled polyester and epoxy resins little more than contact pressures are strictly necessary.

(iii) Cure times generally need to be longer than with liquid resins.

(iv) The use of pinch-off dies is difficult, so parts have to be trimmed after moulding.

(v) The laminator's choice of resins, cloths, fillers and pigments is restricted to what is commercially possible for the supplier.

Moulding Methods

Polyster resins have good flow properties and cure by polymerisation without the evolution of volatiles, so pressure is not necessary to form a laminate, although it is usually desirable in some degree to obtain surface finish and absence of voids. The same remarks apply to epoxide resins if set at low temperature, but not to phenolic and silicone resins. All the following moulding methods apply to the first two resins and some methods may be adapted to phenolic and types of silicone resin.

The Wet Lay-up Process

The mould, of metal, plaster, wood or plastic, is treated with a release agent which is frequently a hard wax, a film such as polyvinyl alcohol or sodium alginate, or a combination of wax and film. If the outside of the article to be moulded requires the better surface, as in the case of a car body, a female mould is used, and vice versa. The surface is then heavily coated with resin which, in the case of polyesters, may be filled, pigmented and rendered self-extinguishing if necessary, and the reinforcement pressed into it. This procedure has the effect of providing some adhesion of the reinforcement to the mould and of bringing entrapped air through the reinforcement. Additional resin is applied as necessary and distributed so as to remove air, which may be accomplished by squeegeeing if the working surface is a woven fabric or by rolling if of mat. In order to obtain a surface as free from blemishes as possible, a filled coat of resin or a thixotropic resin mix may be cured on the mould before laying up the reinforcement. This "gel coat" should not be more than $^{1}/_{10}''$ thick and should, if possible, be flexible. For low production moulding as at present employed for sports car shells, 'bus panels and boats, the resin is usually allowed to cure without external heat, the polymerisation of the resin mix being effected by the inter-reaction of promotor, catalyst, and resin. The hardening of the plastic can be accelerated by hot air or infra red light without change in procedure. This is sometimes desirable in any case, to enable the laminator to gel the resin on a near vertical surface and so prevent its draining from the reinforcement. With these means, the cure can be advanced sufficiently for structures of $\frac{1}{8}''$ thickness to be removed from the mould in about two hours, but further time is needed for them to harden and develop their properties fully.

Where faster setting is necessary hot curing can be employed with a suitable catalyst system, but pressure in some form is necessary to prevent bubbling and delamination. Air pressure may be reacted through a vacuum blanket or higher pressures by means of a pressure bag. A convenient arrangement for large structures is to mount the mould on bogies so that it may be passed through a curing oven. The curing time for any given resin depends upon the oven

temperature, thermal capacity of the mould, and the thickness of the moulding. For large polyester mouldings of, say, $\frac{1}{8}''$ thickness using aluminium moulds and rubber blankets in an oven at 135°C., the curing time would be up to an hour.

Variants of this method are the use of steam or hot water heating of one mould or of a pressure bag. Silicone rubber and silicone modified neoprene rubber bags have found favour on account of superior heat resistance. The use of the vacuum blanket, although yielding pressure only up to atmospheric, assists in the removal of air from the impregnated reinforcement and thus reduces the lay-up time prior to cure. Where there are sharp changes of section or where two good surfaces are required, it is often better to make a back-up mould and include this under the vacuum blanket. These methods have been found suitable for a range of modified phenolic resins in addition to epoxide and polyester resins. In the case of phenol formaldehyde resins, since curing is by a condensation reaction, the reinforcement is usually pre-impregnated and the resins advanced to the " B stage " of cure.

At present glass fibre reinforced plastics are being widely used for aircraft structures, boats, light-weight tanks and translucent sheeting for roofing and screening. None of these, except perhaps the last, and here the translucence needed imposes limitations, is required to be produced with great rapidity and the reasons for producing them in reinforced plastics are technical rather than purely economic. The car bodies and 'bus panels being made in female moulds by the wet lay-up process described, compete with panel-beating of aluminium and usually show a weight saving of up to 25% in addition. The fact has to be faced that the raw material cost of polyester resins and glass fibre is a good deal higher than steel or aluminium. The *entrepreneur* faced with car bodies to make and considering steel, aluminium and glass-reinforced plastics has many decisions to make, e.g. :

1. Can the required rate of production be met, bearing in mind the possibly longer forming cycle entailing the use of more presses and dies, and that for the cold-curing production methods with polyester resins space would be required for " maturing " of the panels after they had been taken from the moulds ?
2. At what premium could such a car be sold ? The advantages to the customers being :-
   (a) weight-saving on body panels and thus better petrol consumption ;
   (b) absence of corrosion ;
   (c) dentproofness, and when damaged, ease of repair ;
   (d) little noise transmission and panel drumming ;
   (e) relatively good heat and cold insulation ;
   (f) increased styling possibilities and, for a time, novelty value.
3. Will the economies in tooling, particularly those effected by the breakdown of the body into a smaller number of pressings, offset the higher raw material cost for the total number of units to be made ?
4. Will the tooling economies be such that substantial changes in the styling of the car can be made annually and so make the public "fashion-conscious " ?
5. How much will be saved in joining together the smaller number of panels ? How much time will be saved in painting and preparing the bodies for this ?
6. Will the lower sound and heat transmission and the possibility of obtaining decorative effect from the mould result in a saving of interior trim ?

With regard to question 1, the *entrepreneur* has at present the methods already described together with the heated matched die process. The curing cycle with polyesters, again on large $\frac{1}{8}''$ thick panels, would not be less than ten minutes, but there are possibilities of faster curing resins such as those based on polydichlorostyrene with a press cycle of 15 seconds following preheat of the material. There is also the possibility of adapting the " electric shock curing " method discovered for certain types of phenolic resin at R.A.E. Farnborough. In this connection, it should perhaps be mentioned that most phenolic resins reinforced with glass fibre give impact strengths of only about 12 ft. lb., compared to 20 - 25 ft. lb. for similarly reinforced polyester resins. There is hope, however, that this gap can be narrowed by resin modification. Flexural and tensile strengths are slightly down but this is due, in part at least, to the need for development of a coupling agent between the phenolic resins and the glass, as has been done for polyesters. Provided that a cheap pre-impregnated reinforcement were to become available, a dry lay-up method with instantaneous, or even fifteen second, cure would be quite attractive.

Once the idea of glass fibre reinforced plastic bodies in place of metal has been accepted, the advantages to customers outlined in question 2 might be expected to carry considerable weight and enable such cars to be sold at a higher price. Large scale use would, of course, bring down raw material cost which, even when corrected for specific gravity, is at present one-third more than aluminium. It may never come about for very large numbers of cars of any particular design, even taking into account economies based on design and mentioned in questions 3, 4 and 5, that reinforced plastics will get down to the first cost of metal bodies. Increased competition might well dictate shorter production runs and more extensive model changes, however, so that the material needing the lower tooling cost would become economic.

The basic fact remains that glass fibre reinforced plastic has just the sort of advantages that any designer might dream up when considering the ideal material for shell structures, and whilst there are at present certain difficulties to be overcome, these should not be allowed to overshadow this important fact.

FUNDAMENTALS OF PHYSICAL METALLURGY

by T. FULLWOOD, L.I.M., C.G.L.I., A.M.I.E.T., A.M.I.I.A., Dip.Ed.

Presented to the Liverpool Graduate Section of the Institution, 23rd February, 1955.

Mr. T. Fullwood

Mr. Fullwood was educated at Hawarden Grammar School, Deeside Technical College and Coventry Training College. He then entered the iron and steel works of John Summers & Sons, Shotton, and working through the laboratory and shops attained the position of Senior Staff Supervisor. He held this position for six years and was responsible for all units of process in the production and finishing of all steel products.

He entered the teaching profession in 1948 at the Denbighshire Technical College and in 1952, moved to Liverpool. Mr. Fullwood was responsible for a group of ten post-graduate lectures on "Metallurgy and the Engineer" which attracted widespread interest, and he has recently commenced another series of ten post-graduate lectures. He also acts in an advisory capacity concerning metallurgical and welding problems.

IF the question were asked, what product of the physical universe has contributed most to the material comfort of the human race and the industrial progress of the world, it could be answered with confidence that metals are entitled to the first place.

The material achievements of metallurgy constitute, however, only a part of its service to human life and industry. It was in the practice of this art more than any other that man developed those mental attributes which are the foundations of science and modern thought. Chemistry developed from the old art of metallurgy, for the first chemists—*'Alchemists'*—were men who tried to convert base metals into gold. Though they met with no success and their efforts had no effect on metallurgy, they actually initiated the studies which have led to the science of modern chemistry.

"Metallurgy may be defined as a highly specialised branch of natural philosophy" — *Edward Elbourne.*

"What subject, when the basic fundamentals are understood, constitutes the most interesting, fascinating, intriguing and even dynamically mysterious of all scientific studies; what subject is free from the terrors of the infinitesimal calculus and is the most logical and comprehensible; the subject which effectively completes the training of *all* engineers?" — *Bureau of Instruction — Carnegie Co.*

This Paper is presented with the express purpose of establishing that physical metallurgy should be included in the training of all engineers and that it should be a compulsory subject on the curricula of all technical colleges.

The atomic or crystal structure of a metal or alloy provides a true indication of the physical and

mechanical properties of that metal or alloy, and a working knowledge of the constitutional diagrams encountered in physical metallurgy would prove undoubtedly a fundamental basis for the determination of the actual microstructures of metals in alloy form, and for possible allotropic modifications that may take place during the heating or cooling of binary, ternary or quaternary alloys.

However, with limited time and space, there will be no attempt to provide a comprehensive theoretical description of involved inter-atomic reactions between the atoms of different metals, or to delve into conflicting hypothetical theories such as those postulated on plastic deformation, age-hardening, etc., or finally to enter into discussion regarding the numerous kinds of phenomena that we inevitably must encounter if we were to try to cover the wide and diverse ramifications of this engrossing subject — physical metallurgy.

Obviously it would be fantastic to imagine that anyone can, in one lecture, do more than touch the fringes of this scientific study, particularly as the nomenclature of the terms is more figurative than literal. This naturally tends to confuse the student, but the enthusiasm and interest that follows this subject makes this anomaly so insignificant as not to matter.

I have yet to meet a student who, having started a study of metallurgy, did not wax enthusiastic Further, having accomplished the art of producing micro-structures of various metals and alloys and attained the ability to interpret the fascinating structures seen under the microscope, his keenness knows no bounds for this all-absorbing subject.

It has never been a case of trying to interest the young engineer in metallurgical operations, but a titanic task to get him to leave the laboratory if he has not completed his particular experiment.

This is a true and sincere report of my own personal experience and no one can deny the tremendous scope afforded to young metallurgists and engineers who care to pursue this very important and certainly one of the foremost subjects today.

Just prior to the sudden catastrophes that befell the Comet jet airliner, the whole world was discussing the potentialities of this wonderful machine. The engineers who had designed this ship had every reason to be very proud of their accomplishments — when 'fatigue' in the metal crystals (so we are told) resulted in the disintegration of the aircraft, with subsequent heavy loss of life.

This serves to prove that it is vital, imperative, that we intensify our studies of the atomic structures of metals and alloys to try to prevent any repeats of these disasters.

No doubt physical metallurgy is also destined to play an important part in atomic research ; how important can only be judged by the fact that we have produced this form of energy from the radioactive metal uranium.

Matter

Through the various senses of sight, touch and hearing, the human intellect becomes aware of the existence of things which collectively are called matter.

Today, apart from the three states, solid, liquid and gas, matter has another concept, i.e., energy ; and it has been proved conclusively from Einstein's equation $E=Mc^2$—(where E is the energy ; M the mass and C the speed of light) that there is a fundamental relationship between matter and energy.

It is well known that isotopes are elements which have given off some of their mass by radiation (Alpha, Beta and Gamma Rays). To cite an example, one gram of radium would take nearly 2,000 years for half of it to change into lead — by giving off some of its mass in the form of certain radiations. This phenomenon is known as the half-life cycle of an element. Obviously, then, there must be a terrific amount of energy released during the change of tiny specks of metal.

Further proof of the opposite reactions is manifest in the natural phenomenon of plant-life where plants absorb energy in the form of sunshine, or light, and increase their mass.

One may ask at this juncture, what has this to do with physical metallurgy? May I reply by stating that this terrific energy concept — now known as atomic energy — is the result of research into radioactive metals such as uranium, and although nuclear physics tends to cover the theory of this research, physical metallurgy is a '*must*' if we are to develop and probe into the physical reactions of metallic crystals and glean greater atomic knowledge.

The Atom

An atom is defined as the smallest part of an element which can enter into chemical combination or take part in a chemical reaction. It is composed of a nucleus made up of protons (positive charges of electricity) and neutrons (neutral). Enveloping this nucleus are clouds or layers forming complete shells varying in radii, in which two electrons (negative charges of electricity) rotate or spin in energy bands and at the same time revolve around the nucleus. The number of these two electron bands make up the total number of electrons circulating in shells (quantum) and this gives us the atomic number of that particular element. To keep the element neutral, obviously there must be the same number of positive as negative charges, with the neutrons making up the mass of the atom, and the total of protons and neutrons gives us the atomic weight ; that is why the atomic weight of an element is nearly double the atomic number, as regards the actual numbers. The old law that the physical and chemical properties are periodic functions of their atomic weight, (which incidentally was established following Mendeleef's periodic table) has now been refuted and Sydney Mosely (Liverpool) instituted what is now known as the new Law — that is — that the properties of the elements are periodic functions of their atomic numbers. Mendeleef's law failed when the isotopes were discovered and Mosely's views endorsed by an investigation into valency of the elements, i.e., the powers of combination with other

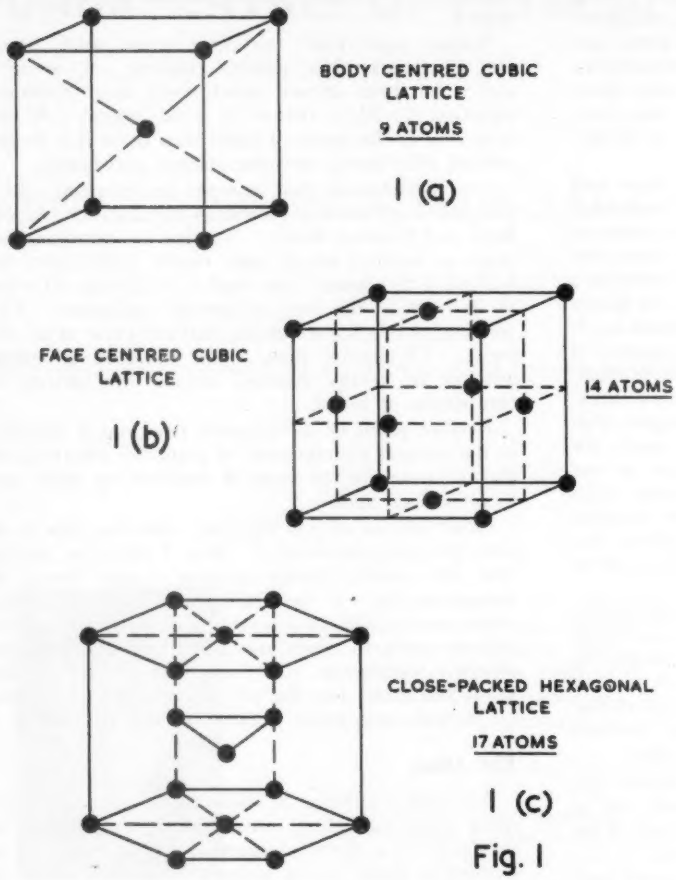


Fig. 1

elements. As combination of elements is due entirely to the reactions of the electrons in the outer quantum shell, they are known as valency electrons.

Molecules

Molecules are atoms of an element joined together, or atoms of different elements joined together to form compounds, e.g., H_2 (molecule of H), H_2O a molecule of water (from two atoms of H + one of oxygen).

Although we have only mentioned atoms and molecules so far we must now proceed to the question, what is a metal? It is defined today as a chemical element which is easy to oxidise to a positive valence. The more electro-positive an element is, the more metallic it appears to be. Metals tend to give up negative charges and become positive, whereas non-metals tend to accept electrons and become negative.

By X-ray diffraction it has been discovered that atoms in metals form a definite three-dimensional pattern repeated indefinitely and these atomic arrangements are truly significant when the physical and chemical properties of metals are compared. One may ask, what is X-ray diffraction?

If a single crystal of a metal is bombarded by X-rays, and placed behind it in the plane of X-rays is a photographic film suitably prepared, the X-rays which meet with little or no resistance will leave a pattern on the film, or if the crystal acts as a diffraction grating by reflection from the atoms we can obtain a pattern on films suitably placed.

From this ingenuous and highly scientific approach for the determination of crystal structure, it has been shown that metals have one of the following atomic arrangements :

(a) body-centred cubic lattice ;
(b) face-centred cubic lattice ;
(c) close-packed hexagonal lattice ;
(d) face-centred tetragonal structure ;
(e) rhombohedral structure.

For our purpose we shall confine our interests to the first three of these metallic structures (Fig. 1).

(a) *Metals with body-centred cubic lattice structures are :*

α-iron, vanadium, α-chromium, molybdenum, tungsten.

(b) *Metals with face-centred cubic lattice structures are*:
copper, gold, silver, γ-iron, aluminium, lead.

(c) *Metals with close-packed hexagonal lattice structures are*:
zinc, magnesium, cadmium, titanium.

If we care to check the melting points of the metals with a body-centred cubic lattice structure, we notice that vanadium melts or freezes at 1720°C., chromium at 1550°C., molybdenum at 2350°C., tungsten at 3267°C. These metals are very hard and close-grained, and are used as an example in high speed steel, which is truly indicative of their properties.

Metals which have a face-centred cubic lattice structure have much lower melting points, e.g., copper, 1083°C., silver, 961°C., gold, 1062°C., aluminium, 658°C., γ-iron stable above 900°C. These metals are all very malleable, ductile and non-magnetic.

Metals with a close-packed hexagonal lattice structure have low melting points, e.g., magnesium, 650°C., zinc, 419°C., cadmium, 321°C. These metals tend to be weak and brittle.

Glancing at the face-centred cubic lattice metals we find that gold, the most malleable and ductile of all metals, can be beaten out into transparent leaves of 1/280,000″ gauge and one grain can be drawn out into 500′ of wire without fracture — wire finer than a spider's web. Silver and copper are also very malleable and of course respectively the best conductors of electricity, and generally speaking metals with this atomic pattern manifest this property of malleability.

Closer inspection of these atomic patterns shows that iron (ferrite) can exist as 'α' B.C.C.L. and also 'γ' F.C.C.L. These different states of iron are known as alloptropic modifications and in view of the important position that ferrous metals occupy in the industrial world, and perhaps as this is my initial Paper, it would be more appropriate that we concentrate our investigations on the ferrous metals and alloys which play such an important part in the work of all engineers.

The first point I must emphasise is that iron or steel is much more malleable at temperatures over 900°C, and as the lattice arrangement at this temperature is F.C.C.L. this tends to substantiate our first observations, i.e., that these metals are malleable. Technically and theoretically, then, we could say that it is not getting the metal hot that

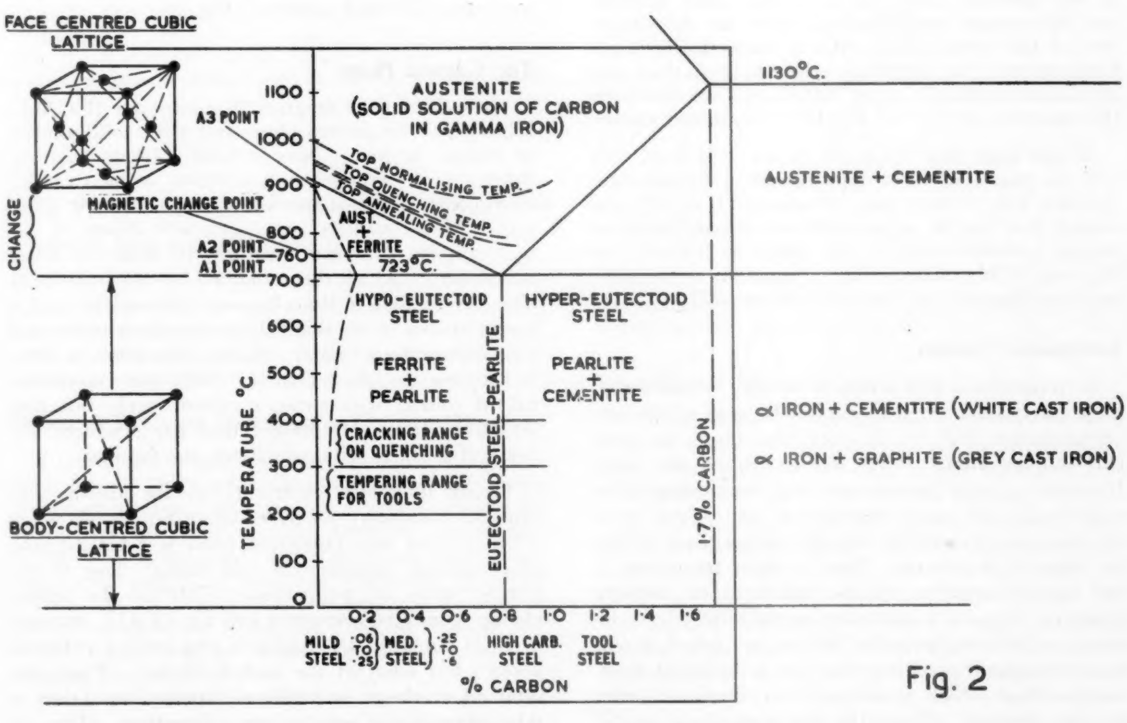


Fig. 2

"Steel Portion" of the Iron-Carbon Diagram

makes it malleable, but that heat effects an interatomic change of lattice structure to F.C.C.L. and then the metal belongs to the malleable class.

To elaborate a little, let us have a look at the well-known and all important iron-carbon diagram (Fig. 2), and then perhaps we can glean fundamentally what actually transpires when these interatomic reactions take place in ferrous metals and alloys (steel).

Though this diagram looks a little disconcerting to the layman, it is simply a graph plotted with iron and carbon in different ratios, to elucidate what happens when iron or these alloys are heated *slowly and uniformly* to a liquid and conversely when cooled slowly and uniformly to a solid. The numerous lines are simply boundaries of different phases that exist at those particular temperatures.

When familiar with the metallurgical jargon used when describing this diagram and its application, it is then that the true significance of this graph becomes very apparent to any users of carbon steel.

Looking at the diagram, let us consider the left vertical ordinate which represents pure iron (ferrite) 100% and along the side we observe the temperature indications. Below the horizontal 720° line marked AC (A=arrest, C=chauffage=heat) we notice that the B.C.C.H. of -iron is manifest. If we heat up this pure iron, when we attain the temperature AC (known as the 'first change arrest') the energy within atomic arrangement is so great that the nine atoms of the cube are preparing to change their position, and this energy oscillation accounts for the expansion of the metal. When AC_2 is reached, 760°C. — Curie point — the atoms are now taking up their new atomic arrangement and at 900°C. AC_3 we encounter the structure of the ' ' F.C.C.L. mentioned earlier.

At this point one might ask or say, "It is all very well to propound these high sounding hypothetical theories, but is there any manifestation at all, any change that can be appreciated to substantiate these atomic reactions that we are asked to believe — as the only visible change that is apparent is the glow (or incandescence) of the very hot metal?"

Interatomic Changes

In reply, may I say that it is very obvious that these interatomic changes cannot be seen under any circumstances due to the fact that there are over two million atoms along the length of one mm. However, a very simple and yet fascinating little experiment will prove conclusively that there must be some very remarkable changes taking place within the mass of the metal. Prior to heat treatment, if the iron is tested it will be found to be strongly magnetic, yet at a temperature around 760°C., if the iron is withdrawn from the furnace and tested, it will be non-magnetic, proving that this property of magnetism about which incidentally we know so little) is most certainly affected by this movement of the atoms to the new position of F.C.C.L. This F.C.C.L. structure which becomes stable above 900°C. is known as austenite, hence austenitic steels, which are generally ni-chrome steel with a F.C.C.L. and are definitely non-magnetic.

Returning to our diagram, let us add a little carbon to our iron and thus convert it to steel, and investigate what transpires during heat treatment and make this application practical. Here again we have a non-metallic element which can exist in different allotropic forms, viz., diamond, graphite, charcoal, etc., and these forms are affected by heat as metallic elements are similarly affected. If we take for our investigation a 0.7% carbon steel as forged or hot-rolled, let us take a spark and hardness test for future reference. Now heat up this steel in the usual uniform manner and we once again observe that at 720°C. we meet our first change point. Now, from the diagram we notice that we do not have to attain a temperature anywhere near 900°C. for a F.C.C.L. structure ; the temperature required is approximately 750°C. What has happened? This is another phenomenon with which we are confronted in physical metallurgy, which is only answerable by theories and hypotheses which tell us that the addition of one element to another tends to lower the change points above the stable B.C.C.L. structure. It appears that the carbon atoms tend to seek new positions on the lattice due to the heat intake and this forces the B.C.C.L. to F.C.C.L. structure more rapidly. Incidentally the carbon atoms take up positions between the iron atoms and form what is known as an interstital solid solution (Fig. 3).

The Gamma Phase

We see from the diagram that austenite (F.C.C.L.) is known as the gamma phase and it is a solid solution of carbon in iron. Now a solid solution correctly defined is a homogeneous, uniform or non-varying constituent and thus must be the best possible structure. Metal workers years ago, well aware of this fact, applied practical measures in order to retain this structure which they obtained by heat treatment. They knew that if the alloy was allowed to cool it would return to its original laminated structure and thus quenching in water, oil, etc., was tried in order to suppress the phase change. They were unsuccessful, of course, with straight carbon steels, but they initiated a train of thought that has produced the wonderful alloys with which we are familiar.

Trying to retain continuity of the theme, i.e., physical metallurgy, let us see what did happen when 0.7% carbon was quenched from a F.C.C.L. (the solid solution structure) in cold water. Due to the terrific range of temperature (760°C.) the lattice change cannot be prevented and the F.C.C.L. changes to B.C.C.L. with the magnetic properties mentioned above ; but what of the carbon atoms? These are retained in almost as highly a dispersed condition as they were in the solid solution structure. This, of course, is the story with which we are all cognizant,

i.e., the quenching of carbon tool steel, where quenching in cold water will cause a drop of 130°C. per second in the steel. This attempt to suppress the F.C.C.L. to the B.C.C.L. structure resulted in a structure known as martensite, which is the most important constituent of heat treated and quenched steels. Obviously if we quenched in oil the speed of cooling would be retarded, and the carbon atoms less highly dispersed and the material would have a softer structure.

It is the arrangement of atoms within any metal or alloy that gives it its specific properties.

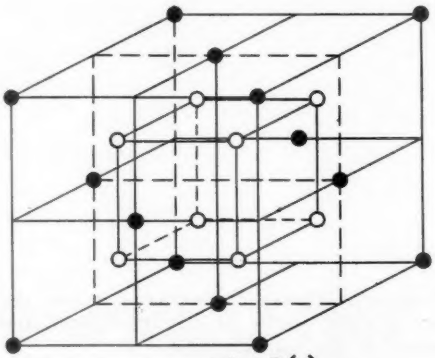


Fig. 3(a)

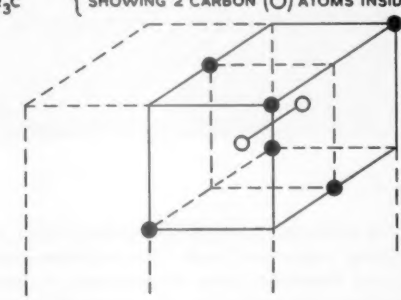


Fig. 3(b)

THE PRODUCTION OF AEROFOIL SECTIONS—

(concluded from page 646)

about .010 to .015. Should the radius of the finishing cutter be of poor quality it will result in malformed leading and trailing edges, which may necessitate re-cutting the whole block.

Effects of Excessive Deflection in Copying Operation

To produce an accurate reproduction of a blade form on the ordinary hydraulically operated stylus equipped machine, all traces of deflection should be eliminated to avoid time-lag between cutter and stylus. This time-lag will result in serious dimensional errors even when an increased stylus size to cutter is used. If the setting of cutter height is in relation to the bottom of the stylus, the irregular shape of the aerofoils producing an uneven side thrust results in oversize chordal widths.

Since many of the leading and trailing edge radii are small, a reduction in cutter size to compensate for deflection is a very serious handicap. Fillet radii from platform face to blade form are invariably produced oversize due to stylus slip.

Inspection of Master Forging Die Blocks

The inspection of the finished die model blocks is in many respects a duplication of the inspection of the initial blade form model block. The main additions to this are the root inspection and locating tabs.

As the volume of material required to make a blade forging is carefully calculated, the tolerances on the root cavity, whilst coarser than on the blade and platform face, are maintained at plus and minus .002.

A smoked glass reading is taken of the root section and any slight correction made before a final reading is obtained on one glass of the locating tabs, root section and the three of four basic blade sections. This glass, after treatment with a quick-drying preserving emulsion, can be placed in store for reference.

THE PRODUCTION OF AEROFOIL SECTIONS AS APPLIED TO THE MANUFACTURE OF MASTER FORGING DIE MODELS

A THESIS by H. BARLOW, A.M.I.Prod.E., of Rolls-Royce, Ltd.

THE most elementary aerofoil section is that with symmetrical shape each side of a common centreline, being of constant form throughout its length. When the form required for this type of blade is produced on a steel template, there are many types of copying machines which will reproduce the form to the desired length. As this is such a simple operation no more need be written about it here.

The types of aerofoil sections involving some specialised equipment in their production are those which are used to divert the passage of gases or to transpose an axial flow into rotary motion, or the reverse. To produce these two effects some angular displacement of the blade ends is necessary, coupled with an increased curvature of the leading to trailing edge centreline.

The degree of displacement and curvature is, of course, the province of the designer, but it is the production of these more complicated forms that will be dealt with.

Agreements on Terminology

In the early stages of compressor blade production, each of the individual manufacturers developed their own terms of reference towards blade form and root fastening datums, which, whilst quite satisfactory when contained within their own establishments, caused considerable confusion when the expansion of the industry brought with it the necessity for technical discussions on blade design and development.

The Society of British Aircraft Constructors, in agreement with the American Aircraft Industry, decided that the three main datums should be known as:

the axial plane ;
the transverse plane ;
stacking point.

The Axial Plane — is that parallel to the centreline of the engine or compressor.

The Transverse Plane — is sectional across the compressor, at right angles to the axial plane and usually central to the root fastening.

The Stacking Point — is the intersection of the axial and transverse planes view square to the root.

Basic Aerofoil Sections in Relation to Engine Axis

The chord line of a blade section is, as its name implies, the line passing through the leading and trailing edges at the maximum width of the individual section. Chordal widths are also measured along this line. As the twist of the blade along its length increases, so increases the angular difference between the chord angles of adjacent sections.

The designer, having established the basic section requirements, can then convey the section's relationship to the blade root by quoting the angle between the chord line and either the axial or the transverse plane.

These chord angles are not used by the toolmaker in the actual production of the die models, but nevertheless form a very desirable detail on the blueprint, as the toolmaker can, if necessary, form a very good mental picture of the blade twist.

Determination of the Ruling Angles

In connection with simple ruled blade forms, the ruling angle is that through which the blade form must be viewed to bring the leading and trailing edges parallel. In this position, the complete concave or convex surface of the aerofoil may be produced by machining straight lines from one basic section to the other.

It will be appreciated that the straight lines must coincide with the basic aerofoils at each increment, and therefore provision is made in the subsequent machining operations to tilt the block being manufactured through the angle, square to the ruling angle to bring this about.

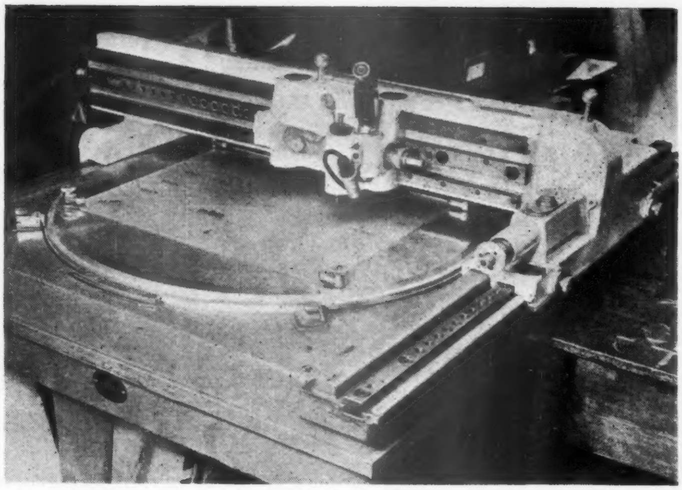


Fig. 1. Machine for producing glass plate lay-outs.

When the aerofoil under consideration is a taper ruled form, the ruling angle is supplied by the Design Office. In a form of this type the ruling angle is related to chordal widths and the apex dimension.

Perspex and Glass Plate Layouts

To the tool-maker the first necessity is the Perspex or glass plate layout, usually at a scale of 10 : 1. These plates are plotted with great accuracy on machines especially designed for this type of work (Fig. 1), and show the actual aerofoil shape of the basic sections and their relation to the template setting line, i.e., the ruling angle, the centreline of dies, die datum, or any other necessary datum peculiar to the aerofoil to be manufactured.

The principle datum not yet mentioned in relation to the aerofoil is the most important, namely, stacking point, which has been described previously as the intersection of the transverse and axial planes when viewed through the root.

The importance of this point lies in the fact that throughout all the subsequent operations on both blade form model blocks and die models, reference is always made to the stacking point.

In the past it has been necessary to produce both nominal layouts and layouts with contraction allowances. It is now possible, with the Projection Grinder shown in Fig. 2, to reduce the magnification by adjusting the mirror position, thereby producing from a 10 : 1 nominal layout, gauges with contraction allowances incorporated.

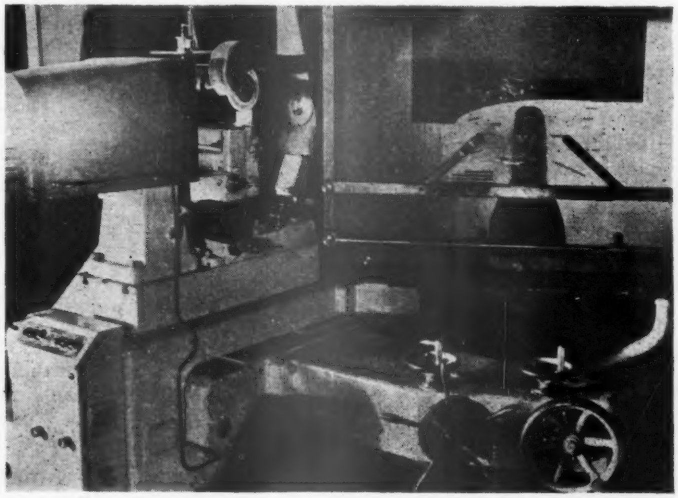


Fig. 2. Optical Projection Grinder.

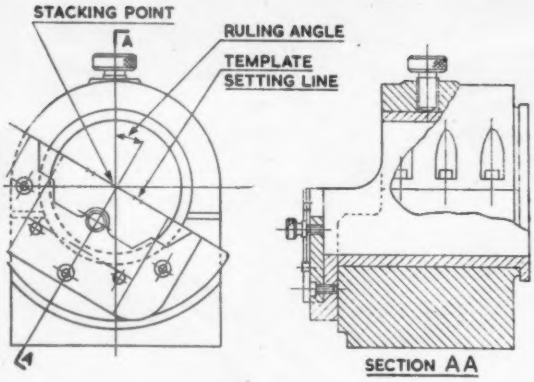


Fig. 3. Barrel type holder.

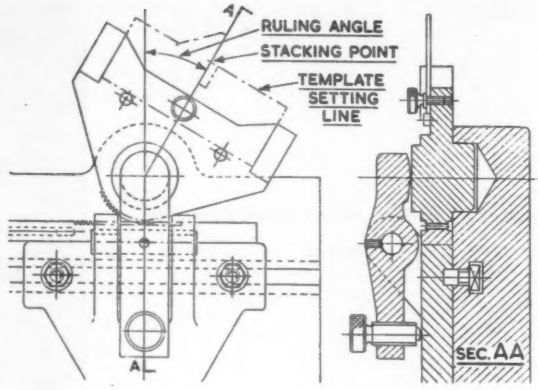


Fig. 4. Pivot type holder

Production of Basic Section Sheet Gauges by Projection Grinding

At the outset it is essential to establish a standard to which the gauge blanks are produced, also to standardise the height at which stacking point is to be produced from the base of the gauge. The advantages of this will be apparent when it is borne in mind that the four gauges required to produce a set of simple ruled blade form model blocks, i.e., concave and convex sides, are produced separately and must be related to each other for subsequent operations.

Two types of mounting are in current use for maintaining the height of stacking point and its position from the side of the gauge. They are the barrel holder and the pivot holder (Figs. 3 and 4).

In the former, the barrel is placed in the projector beam with its axial centreline coincident with the intersection of a vertical and horizontal line on the projector screen.

A strip, or button, location is made on the face of the barrel to enable the base of the gauge to be placed at the predetermined distance from the centreline of the barrel. It follows that at whichever angle the barrel is rotated through, the base of the gauge remains at a constant distance from the rotational axis of the barrel. This distance is the stacking point from the gauge base and is also coincident with the screen centrelines.

An advantage of this type of mounting is that after the initial setting of projector screen and barrel, no further setting gauges are required. Weighed against this is the disadvantage of its being a single-purpose machine.

With the machine using the pivot type holder it is necessary to use a standard setting gauge with each new ruling angle set, but the machines are usually multi-purpose.

Uses of Datum Lines and Stacking Points

As previously stated, the glass plate layout usually carries, as well as the blade profile, such datums as centreline of dies, die datum, template setting line, transverse and axial planes.

The template setting line is actually a datum line square to the ruling angle to enable the projector operator to set the gauge holder at the correct angle by inserting first a setting gauge, the setting face of which must coincide with the template setting line when the face 'A' (Fig. 4) passes through stacking point. The setting gauge is removed, gauge blank inserted and locked.

When the layout is placed on the screen with the centreline of dies and die datum coincident with the vertical and horizontal centrelines of the screen, the machine is ready to grind the gauge profile. This set-up produces the gauges and consequently the blade form model blocks, with a base parallel to the template setting line.

The centreline of dies and die datum are used also in later stages when checking the actual die blocks.

The axial and transverse planes shown on the layouts are used when the item under inspection is (as is usual with fixture components) being checked in relation to these two actual engine datums.

Simple Ruled Mechanisms

A simple ruled mechanism is basically an attachment for cutting simple ruled forms. The mechanisms are anything but simple. The attachment is mounted on to either a vertical or horizontal milling machine enabling an angle bracket to be pivoted in a plane square to the cutter spindle. On to the angle bracket is mounted the block or blank into which the aerofoil is to be cut (see Fig. 5).

Mounted in tandem with the block is a gauge

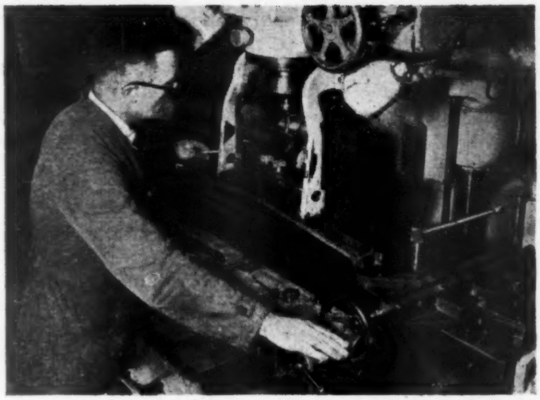


Fig. 5. Mechanism for producing simple ruled forms.

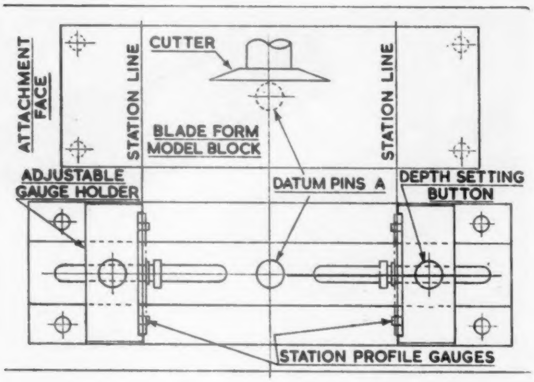


Fig. 5a. Diagrammatic set-up for simple ruling

holder with adjustable gauge positions which are preset about a location hole to bring the gauges into the correct relative position.

It will be seen from the illustrations that the station, or section, positions do not necessarily sit equal about the centre datum hole. This condition may arise for varying reasons, the principles being, placing of datum holes, (for convenience of later operations) on a line with a "central" station, which itself may not be actually central to the two basic sections, or, since an end face of the finished blade form block is required for datum purposes and a standard amount is left on this face to allow for tracer over-run, it is more convenient to offset the setting pin.

The probes and cutter are set to height by using the two centre datum pins 'A' and the depth is set by the use of two detachable setting buttons mounted on the gauge holders and slip gauges direct from the attachment face before the block to be cut is fastened into position. These settings, in conjunction with a clock indicator on the machine knee and two other clock indicators operated direct by the probes, complete the basic attachment, further details of which may be seen in the illustration.

Inspection of Three-Dimensional Aerofoil Model

Many proprietory machines are made on which it is possible to inspect an aerofoil section, but of most it may be said that they are fairly expensive. A most reasonably priced fixture may be made, which, when used in conjunction with a standard projector, will cover almost the whole range of sectional inspection for which layouts are available (Fig. 6).

The fixture comprises a roller-mounted table which will pass with the block or tool to be inspected beneath a cross beam which in turn carries a small vee-slide. The beam and slide are the means of moving a scribing needle across the aerofoil under inspection. As the needle crosses the aerofoil, it is allowed to fall in the vertical direction by the use of a double vee-ball tracked slide which carries at its upper end a second needle, lightly spring-loaded, to trace the path of the lower needle onto a lightly smoked glass.

To facilitate the positioning of the aerofoil in relation to engine axis, die datums, or template setting lines, the lower needle is flatted to the centreline of its diameter and held in a collet which is arranged to index through 180°.

This enables the operator to date with the needle flat on the side of the component and move over on

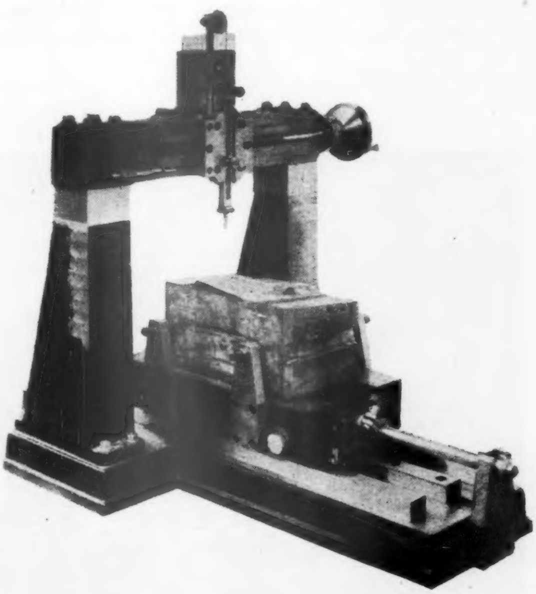


Fig. 6. Smoked glass aerofoil inspection fixture.

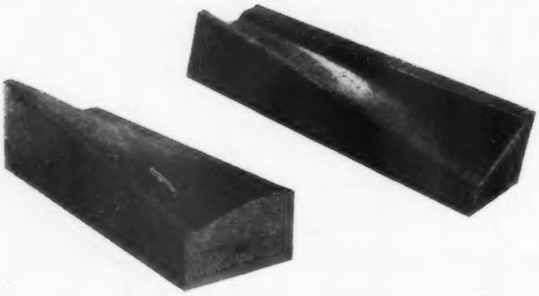


Fig. 7. Model blocks, concave and convex forms.

the cross beam to the estimated position of the aerofoil centreline. From this position, having first noted it on the main fixture datum by the use of a micrometer head and slip gauges, a vertical line is traced on the smoked glass. A horizontal line is traced on the glass by raising the lower needle point, allowing it to rest on slip gauges the estimated height of die datum. The horizontal vee-slide is then operated to take the upper needle across the glass.

These two datum lines can be adjusted after the first projection to the precise positions in relation to the aerofoil, and the form then checked to the layout.

It should be noted that although the vertical slide is counterbalanced to reduce the slide's effective weight to about one ounce, it is not practical to trace any form in the direction which makes the needles rise. To avoid the knife-edge of the needle cutting into the aerofoil, the reading should be made from the gate to the lowest point of the section. This should be repeated from the opposite edge gate, and the needle flat should be trailing in all cases.

Station or section lengths are set, using slip blocks and an end stop on the main table slide.

In the production of die models the blade form is usually produced as two separate blocks, concave and convexed, and then, having passed inspection, are copied into the die model blocks on the normal copying machine.

As there is usually an angular relationship between template line and die datum, it is a great advantage to have a small (say .250 dia.) datum hole in the end of the aerofoil model block at a constant figure below stacking point. This single datum hole enables the copying machine operator to position the aerofoil in relation to the die blank for both vertical centreline and for depth of die datum (Fig. 7).

The station position on the aerofoil block is also at a constant distance (say .750) from one end. This, of course, is the only remaining datum required finally to position the aerofoil to the die block.

The Generation of Taper Ruled Forms

The taper ruled form differs from the more normal simple ruled in the fact that its ruling lines are not parallel, but are cut towards a common apex viewed square to the ruling angle.

As this apex may vary in distance from the basic section by a matter of feet, it is not convenient to swing the aerofoil block by pivoting a plate at this apex point. To overcome this type of set-up, a taper ruling attachment may be mounted on to a vertical milling machine, which, whilst passing the aerofoil block and gauge holder through an almost circular path, does not rely on a fixed pivot pin.

The taper ruling attachment incorporates into the normal ruling system two sine bars which are used in conjunction with each other to create a differential

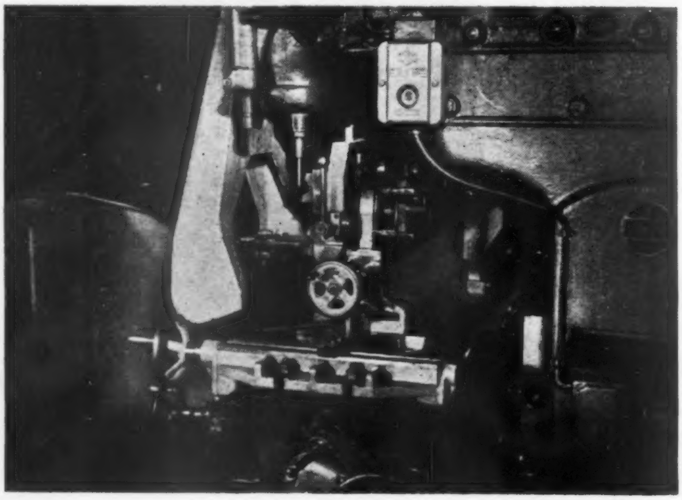


Fig. 8. Attachment for producing taper-ruled forms.

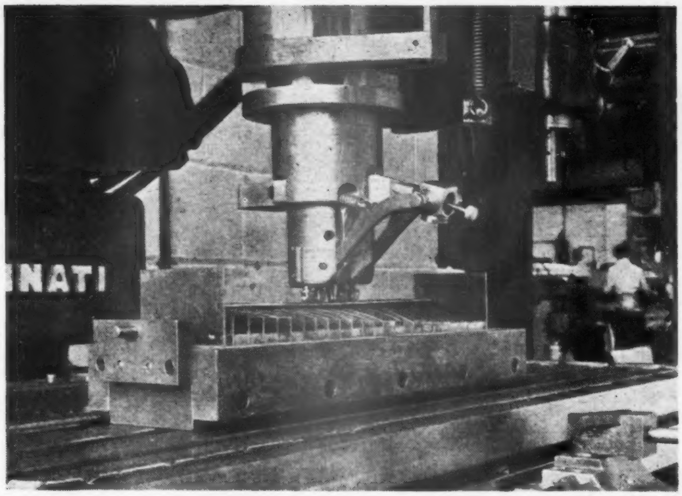


Fig. 9. Attachment for unruled blade forms.

in the rate of rise of two vertical slides. The sine bars may be seen behind the block and cutter in Fig. 8. To operate the sine bars, which are of course only used after the initial setting, and increment the workpiece across the cutter edge, it is only necessary to turn the small handwheel on the end of the fixture, which draws both sine bars along a horizontal slide and in turn drives the vertical slide anchor pin either up or down at a rate dependent on the angular setting of the bars.

By this set-up any apex length may be obtained, from actually coincident on the end station or at infinity.

Reference to Fig. 8 will also make a little clearer the section on simple ruled blade forms, in particular, the pivoting of the whole attachment by the screw in the foreground and the disposition of the workpiece, gauges and clock contacts.

Unruled Blade Forms

As the engineering industry advances, it seems to become increasingly more complicated and the designers of both turbine and compressor are certainly in the forefront of this advance, as a result of which the toolmaker is presented with another and slightly more difficult shape.

The difficulties presented by requiring an aerofoil without possibility of straight line ruling are many, but that which is most difficult is the production of such a form without the usually attendant waves along the blade length.

To overcome this a small attachment was made (the writer personally designed and was responsible for its manufacture), to fasten on to the stylus bracket of a suitable copying machine (Fig. 9), suitable inasmuch as the stylus bracket and housing must be strong enough to withstand the pressures involved.

The use of this attachment involves the setting out of layouts for the required aerofoil for each half-inch of its length with an additional three gauges at each end to cover the normal allowances for stylus over-run.

Having produced the section gauges in the normal way, they are mounted into a standard base together with packing strips and restrictor plates are fitted at each end. These plates are to prevent the rod from moving along should one of the small track wheels cease revolving.

The attachment fitted to the stylus bracket consists of a main housing into which are fitted four track plungers spaced along the line of traverse at $\frac{1}{2}''$ and $1''$ each side of the stylus. The contact ends of these plungers are fitted with small rollers which will travel along a $\frac{1}{8}''$ dia. rod of silver steel, the rollers having a concave radius on their top diameters to keep the rod on track. Each pair of plungers is connected by a small ball toggle, and set between the plunger and around the connecting toggle is a lever with a 4 : 1 ratio.

With a spring load of 9 lb. on the lever, a load of 18 lb. is exerted on the roller ends. This moment is sufficient to bend the silver steel rod but not sufficient to produce permanent deflection. As the true stylus rides on top of the silver steel rod, the diameter of the rod is the controlling factor in terms of cutter diameter and any settings must take into account the diameter of the rod.

This method of cutting unruled forms produces an almost perfect curve and leading and trailing edges are produced quite accurately by cutting from the flash positions to the lowest part of the form.

A refinement of the attachment is a wedge plate through the stylus operated by ball joints connecting the two spring levers by which, should the rollers by some mischance run off the wire at any position, the work is automatically taken away from the cutter.

When the unruled blade form model block is produced by setting gauges into a holder and filling in with such materials as Kemdent or Cerrobend, it is very difficult to file or scrape away excessive material

Fig. 10. Die model block, showing root insertion.

without producing a series of flats in between each section gauge. These flats are transmitted from the model to the close forged blade form and can be felt quite easily, even with such small errors as .002, by running the finger along the blade length.

As the gauges are required in both systems, in terms of cost they cancel out, but the time involved in filling in the box and filing off the excessive material is completely avoided by the use of the attachment described.

A further point which makes for machine cutting an unruled aerofoil is the fact that most, if not all, of these filling media are decidedly unstable when considered in the light of tolerances of .002. In view of this instability any form developed by filling must be copied onto a steel block almost immediately the medium is firm enough.

Master Forging Die Model Blocks

One of the earlier operations in the manufacture of die models is the construction of the root aerofoil face. This is commonly known as the platform face, and is that face of the root over which, in the case of compressor blades, the air passes, and therefore its correct shape should be a small area of the wall of a hollow cone in the case of stator blades, and a small area of the outside of a shaft in the case of rotors.

If these conditions were satisfied completely, the close forging of the faces would become somewhat difficult, as the die face itself would become re-entrant and make it impossible to remove the forgings from the die block. To overcome this difficulty, the boundary lines of the area are preserved in shape and the necessary draw put into the die to facilitate the removal of the work.

Cutting this shape direct into the master die model block involves quite a tedious machining operation and a considerable amount of bench time. Inserting a false root into the master (Fig. 10) die block in the form of a strip dowelled and screwed enabled the root face to be cut horizontally. In this position the radii can be stepped out and the long boundary lines joined to the radii. If the root insert is then tilted through the draw angle square to the die datum, the complete face is formed by passing the ball end cutter across the work and blending with the boundary lines and radii lines for depth. All of these operations being carried out from a common datum hole, it is quite convenient to relate the platform shape to the centreline of dies and die datum. This root insert, after trimming and checking is fastened into the model die blank and the aerofoil shape of the blade form copied from the ruled aerofoil block.

Prior to the final fitting of the root insert, there are several operations which must be carried out and noted. Firstly, the cranking on the top face of the die model block is roughed out, leaving a projection which is large enough in length and width to cover the whole of the blade form, pips, root width at die datum, gate and guttering.

The root insert is meanwhile checked to confirm its platform face shape and to determine the distance of its several inspection points from the back face. Care is taken with this dimension at the initial laying out of the model die, to make certain that the joint made by this face and the model block proper do not coincide with a station position on the blade form. If this precaution is not taken, there is the possibility of an incorrect reading of the blade form on the smoked glass check when the needle runs in the split.

When the root effective thickness is known, the die model block can then have its root insert slot milled in the correct position from the end gauge face, which, for the purpose of finally matching top and bottom half die blocks, is made a fine limit from the basic blade section.

The remainder of the root thickness is roughed out in the die block and a small datum hole bored into the end of the die usually 1" below stacking point.

The copying of the blade form into the die model may be carried out on any precision copying machine on which deflection of the stylus is restricted, or on the Nassovia type, where the stylus is electronically coupled with the hydraulic system.

To set the blade form model block into its correct position, it is necessary in all but a very few cases to tilt it through the angle which the die datum makes with the template setting line. This may be done on an ordinary angle plate.

In this position, to relate stacking points on the blade form model and die model a sine and cosine of the above angle will give the lift and move over from one to the other. Normal dating is then done to stylus and cutter.

The cutter for roughing should be of a high speed tool steel and may be of the slot drill type with a full radius ground on the bottom, whilst for finishing a tungsten carbide cutter with precision ground radius should be used with a small cut at increments of

(*concluded on page* 639)

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

SEPTEMBER, 1956

Monthly Bulletin

The April issue of the Bulletin contained an article on the six-month student scheme. Nearly 100 young engineers from member firms have now taken this advanced course of training ; firms who have participated in the scheme include manufacturers of light and heavy electrical equipment, motor cars, locomotives, diesel engines, machine tools, small tools and gauges, metal boxes and other pressings, aircraft, boilers, etc. Each student is attached to a PERA research team, and obtains direct practical experience of the techniques developed by PERA for solving a wide variety of production problems. In addition, lectures are given by senior research engineers, and visits are made to factories using modern production methods.

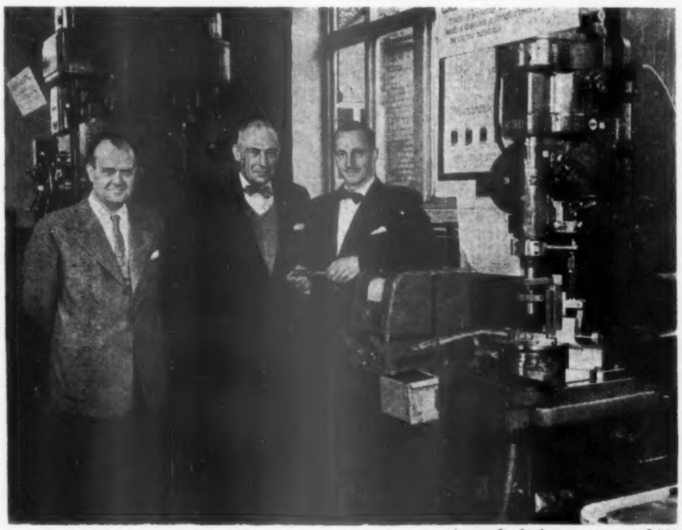
Summaries of recently published research reports were given in the May and June issues of the Bulletin. Nearly 17,000 copies of the Bulletin were distributed to members during the quarter, and this resulted in requests for approximately 17,000 reprints of articles, research reports, etc., mentioned in the Bulletin.

Research

Recommended sizes of blanks for rolling Unified Screw Threads were given in a research report on thread rolling issued to members in May. The blank sizes include an allowance for possible thread form errors, and should result in the production of Unified Fine and Coarse threads giving class 1A and 2A fits in accordance with B.S. 1580 : 1953. The recommendations are based on investigations in which $\frac{1}{4}''$ and $\frac{3}{4}''$ diameter threads were rolled in alloy steels, brass, duralumin, and Nimonic 80. The report should be of great assistance to draughtsmen and designers in specifying correct blank sizes.

Other publications which have recently been issued to members include a research report entitled 'Effect of Reaming Conditions on Hole Accuracy and Surface Finish'. The investigation revealed that increasing the reaming speed, depth of cut, and feed rate above certain critical values caused a marked deterioration in hole surface finish and accuracy. Accuracy did not, however, deteriorate quite so rapidly as surface finish, and hence if some increase in surface roughness is acceptable, cutting speeds can be increased without great loss of accuracy. At cutting speeds below the critical values mentioned in the report, there was no significant difference in the performance of straight flute and spiral flute reamers.

Practical work has been completed in an investigation of the effect of drill point shape on drill life ; the results show that substantially different point



Dr. Galloway (right), discussing PERA's machining researches with Dr. J. W. Barker (centre), President of the American Society of Mechanical Engineers, and Professor Hallendorf (left), of the Royal Swedish University of Technology. Dr. Barker visited PERA following a tour of the United States of America by Dr. Galloway.

(*concluded on page* 648)

CONFERENCE OF STANDARDS ENGINEERS

FOLLOWING the success of the Conference of Standards Engineers held last year in collaboration with the British Standards Institution, a second Conference was organised by the Institution of Production Engineers and the B.S.I., and took place at Standards House on 24th May, 1956.

On this occasion, the programme differed slightly from the first Conference. Instead of being entirely devoted to discussion, the first part of the programme took the form of a Paper given by Professor H. W. Martin, of Rensselaer Polytechnic Institute, New York, whose subject was: "Standards — The Standards Engineer and Economic Production".

Aspects of standardisation well-known to those attending the Conference were mentioned, but coming as they did from the other side of the Atlantic, were seen in a somewhat different light. Professor Martin's Paper was very well received, but obviously could not shed any new thought on the problem of standardisation, preaching, as he did, to the already converted.

During the afternoon, the Conference settled down to the more domestic problems. Mr. T. A. C. Sparling, M.I.Prod.E., initiated a very helpful discussion on publication of information regarding International Standards, with the result that B.S.I. have agreed to do everything possible to bring to the notice of interested parties the activities and new developments in this field.

One suggestion put forward by the British Standards Institution was that training courses for Standards Engineers could be initiated. It was agreed that this could well form a subject for discussion at the next Conference, which will take place in about six months' time. The B.S.I. also reported that Data Sheets were now being produced and that the Committee on Coding was very active.

The interest shown in these meetings and the high rate of attendance indicate that they meet a real need, and the Joint Advisory Committee of the I.Prod.E. and B.S.I. are already making plans for the Third Annual Conference of Standards Engineers, which will take place early in 1957. Full details will be announced in the Journal Supplement in due course.

PERA QUARTERLY NEWSLETTER—

(concluded from preceding page)

shapes are necessary for maximum drill life when machining different ferrous materials. Some experiments are being made to determine the most suitable punch and die radii for maximum depth of draw in a wide range of materials. A report on de-burring with power tools (the fourth in the series on deburring) has been completed, and considerable progress has been made in the preparation of the fifth report, which deals with barrelling techniques. The automation research team has been doubled in size to expedite research into work handling and positioning, and visits are now being made to factories in connection with the investigation. Progress on research into vibration and chatter has included the identification of modes of vibration occurring in cylindrical grinding machines and the effect of vibration on lobing of cylindrically ground workpieces. Methods have also been developed for determining the natural modes of vibration of centre lathes.

Visit by Dr. Galloway to U.S.A. and Canada

Dr. D. F. Galloway has just returned from a two-month visit to the United States of America and Canada, where he gave several lectures to the American Society of Mechanical Engineers, and to the Engineering Institute of Canada. In addition, he studied developments at leading production research laboratories. The American Society of Mechanical Engineers honoured Dr. Galloway by inviting him to deliver the Calvin Rice Memorial Lecture at the Society's Semi-Annual Meeting in Cleveland. Dr. Galloway was also elected a Life Member of the Society. The visit was made at the suggestion of PERA Council to convey to American engineers PERA's appreciation of the gifts of machines, instruments, and other research equipment received from the U.S.A. through the International Co-operation Administration (formerly F.O.A.).

Dr. Galloway's lectures in various industrial centres were attended by hundreds of engineers, some of whom are arranging to visit PERA laboratories. Among the visits already carried out was that of Dr. J. W. Barker, President of the American Society of Mechanical Engineers. Another result of the tour is that Canadian companies may for the first time subscribe to PERA and enjoy the benefits of its services. Advances which Dr. Galloway saw in the U.S.A. will assist in the further development of PERA's research activities.

MATERIAL UTILISATION

THE Research Committee, following the publication last year of their Report entitled "Material Utilisation in the Metalworking Industries", decided that similar investigations relating to other materials should be made. Consequently a new Sub-Committee was formed and given the following Terms of Reference:

> "To investigate, within the specified fields, the use of raw and process materials in the engineering and allied industries, *and other production processes*".

Mr. R. N. Marland, B.Sc., A.M.I.Mech.E., M.I.Prod.E., Director, Messrs. John Wright & Co. Ltd., Birmingham, was invited to be Chairman, and the Sub-Committee has recently been divided into four Panels, as follows:

PANEL A — Finishing (painting, enamelling, lacquering, chemical finishes and plated finishes)

Mr. W. J. Smith (Chairman), Chief Chemist, Industrial Division, Lewis Berger (Gt. Britain) Ltd.
Mr. J. H. Gray, A.I.Mech.E., Managing Director, Escol Products, Ltd.
Mr. A. W. Wallbank, B.Sc., F.R.I.C., Managing Director, Ionic Plating Co. Ltd.
Dr. D. N. Layton, Technical Manager, Ionic Plating Co. Ltd.
Mr. W. F. McDonald, Production Engineer, Domestic Electronics Division, E.M.I. Ltd.
Mr. I. Walker, Head of Laboratories, Briggs Bodies Ltd.
Mr. J. Adcock, I.C.I. Ltd. (Paints Division).
Mr. J. Hooper, Editor, "Sheet Metal Industries".

PANEL B — Ancillary Materials, with particular regard to packaging, cartoning and shipping materials

Mr. H. L. Madeley, A.M.I.Prod.E. (Chairman), Production Manager, Hoover Ltd.
Mr. F. A. Paine, Head of Packaging Laboratories, Printing and Allied Trades Research Association.
Mr. K. S. Arnold, Production Engineer, S. Smith & Sons Ltd.
Mr. R. T. Webb, Production Engineer, Philips Electrical Ltd., Mitcham Works.
Mr. E. A. Shipley, Nuffield Central Research Laboratories.

PANEL C — Alternative Materials (e.g., powder metallurgy, plastics, ceramics, etc.)

Mr. S. A. Ede (Chairman), Technical Director, James Ferguson & Sons Ltd.
Mr. J. E. Poulter, A.M.I.Prod.E., Works Superintendent, Doulton Industrial Porcelains Ltd.
Dr. T. H. Blakeley, Head of Research Department, The Morgan Crucible Co. Ltd.
Mr. G. R. Bell, Metallurgist, Powder Metallurgy Ltd.
Mr. G. A. Clowes, Consulting Engineer, A. G. Hayek & Partners Ltd.

PANEL D — Indirect Materials (e.g., degreasing solutions, wetting agents, lubricants, cutting oils, etc.)

Mr. B. G. L. Jackman, A.R.Ae.S., M.I.Prod.E., M.I.I.A. (Chairman), General Manager (Brake Division), Lockheed Hydraulic Brake Co.
Mr. W. F. McDonald, Production Engineer, E.M.I. Ltd.
Mr. R. Tilsley, A.M.I.Prod.E., Research Manager, Production Engineering Research Association.
Mr. H. Beeney, Works Metallurgist and Research Engineer, Alfred Herbert Ltd.
Mr. A. Taylor, Head of Products Development Department, F. W. Berk & Co. Ltd.
Mr. H. L. Quick, Assistant Chief Metallurgist and Chemist, Humber Ltd.
Mr. H. Stafford, A.M.I.Prod.E., Standards Engineer, The United Steel Co. Ltd.
Mr. J. R. Widdowson, M.I.Prod.E., Chief Production Engineer, Samuel Fox & Co. Ltd.

Notes for Guidance are being prepared by the various Panels and these are to be circulated to all Section Chairmen, requesting them to form Working Groups in each Section area for the purpose of collecting Case Studies for submission to the respective Panels.

Case Studies are expected to indicate resultant savings by the proposed use of alternative methods or materials and as a result of intensive work study.

The names of the individual companies from whom the Case Studies are obtained will not be disclosed.

The Report. Following examination and classification of the Case Studies by the respective Panels, it is the intention to collate them in the form of a comprehensive Report for general use in industry.

The Sub-Committee earnestly hope that there will be a ready response from all Sections in setting up Working Groups to provide Case Studies for possible inclusion in the Report. The need for intensified work study is fully realised throughout industry and though the field to be covered within the Terms of Reference is vast, the Research Committee earnestly believes that the Panels are well able to produce a Report which will be of great value to industry in general.

MATERIALS

old method

CASE STUDY No. 7

Materials Handling applied to a Finished Parts Stores.

The Company. A large Midland Company engaged in light engineering for the motor car industries, and comprising several product divisions.

The Problem. In one of the divisions, small components are received from the Machine Shop and from outside suppliers, and are accumulated in a Finished Parts Store, to be issued in balanced sets of parts as called for by the production programme. Some reorganisation was called for, since existing storage capacity was insufficient for the anticipated increase in monthly product turnover.

The goods were checked into the Store by means of a computing machine and were then placed in static storage bins of the orthodox type. Batches to be issued were taken out of the bins by hand and quantities again counted on a computing machine.

The disadvantage of this method was the manhandling of components in and out of the bins.

HANDLING

new method

The goods are checked into the Store by means of a computing machine and are placed in standard work boxes, which are then stacked on the floor. Batches to be issued are made up from quantities in the standard work boxes; broken quantities are counted on a computing machine.

Note: The number of different components in this Store is relatively small, but many of them exist in large quantities. In other words, there are many standard work boxes of each component. If this condition did not exist, then the following advantages would not be gained:

(a) handling is performed in loads of one or more standard work boxes at a time;

(b) recounting is not necessary where complete box loads are issued;

(c) there is no damage to delicate surfaces or external screw threads.

Cost Comparisons

1. Two Storemen were employed when the Assembly Shop which they served was producing at a monthly rate of 40,000 units and large static bins were used.

After the change of method, two Storemen were still employed and 4,000 standard work boxes, $12'' \times 12'' \times 6''$, are used for storage. The Assembly Shop is now producing at a monthly rate of 74,000 units.

The increased efficiency consists mainly in the handling of a large proportion of the issues in known precounted quantities in standard work boxes (miniature hand pallets).

2. 58 static storage bins for components for a programme of 40,000 units cost £457. 108 static storage bins for components for a programme of 74,000 units cost £850, or £393 additional capital expenditure. 4,000 standard work boxes cost £1,200. Therefore, the additional capital outlay to meet the increased programme and to change over the Stores system was £807, being the difference between the cost of adding to the static bin capacity and the *total* installation of work boxes. Any recovery value for the existing bins and racks has been omitted, as this is not known definitely.

The labour cost was £784 per annum and on the assumption that under the old system of man-handling in and out of bins this would have increased in direct proportion to the output, would now be, with static bins, £1,451 per annum. Therefore, the new system gives an annual saving in labour of £667 and the capital outlay is recovered in about 15 months.

institution notes

Wolverhampton Honours the President

The Wolverhampton Section Committee are arranging a small private dinner party in honour of the President of the Institution, Mr. E. W. Hancock, M.B.E., which will be held at the Mount Hotel, Tettenhall, on 18th January, 1957.

Mr. Hancock was largely instrumental in the formation of the Wolverhampton Section in 1944, and the Committee are anxious that all members who originally joined the Institution in Wolverhampton, and have since moved to other areas, should have an opportunity of attending the Dinner. Any such members are therefore requested to contact the Section Secretary, Mr. R. J. Sury, at the Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.

Presentation to Mr. J. W. Berry

This silver cigarette box, suitably inscribed, was recently presented to Mr. J. W. Berry, M.I.Prod.E., by the Joint Examination Board, in recognition of his 25 years' outstanding service as Chairman of the Board.

Mr. Berry, who is one of our most widely-known members, joined the Institution in 1928.

Mr. P. H. F. Burton, Graduate, has relinquished his position as Project Engineer at Handley Page (Reading) Limited, and has taken up an appointment as Chief Production Engineer in the Bristol Aeroplane Works, Cardiff. Mr. Burton was a member of the Reading Section Committee.

Mr. M. D. Drinkwater, Graduate, has relinquished his position as Technical Representative with Skefko Ball Bearing Co. Ltd., and has joined Wickman Limited, Coventry, as a Sales Engineer.

Tribute to Mr. B. H. Dyson

Mr. B. H. Dyson, Member, General Works Manager of Hoover Ltd., Perivale, was recently made a Director of Hoover (Electric Motors) Ltd. He has been a Director of Hoover (Washing Machines) Ltd. since 1948.

Mr. Dyson has taken a leading part in the development of the Institution, as a Member of Council, as Vice-Chairman and, subsequently, Chairman of the Research Committee, as Joint Chairman of the Joint Committee on the Measurement of Productivity with the Institute of Cost and Works Accountants, and as a member of the Awards Sub-Committee. He has also served on the Education and Membership Committees, on the Conference Organising Committees, and the London Section Committee.

On completion of Mr. Dyson's term of office as Chairman of the Research Committee, last July, the Committee unanimously recorded their appreciation of his stimulating leadership and personal enthusiasm, which have been largely responsible for the initiation and successful fulfilment of the various projects undertaken during the past few years.

NEWS OF MEMBERS—
(concluded from facing page)

Mr. Eric Ward, Associate Member, has relinquished his position as Manager of the Production Division, British Institute of Management, to become Technical Director of L. W. Bailey & Partners Limited, Industrial Consultants.

Mr. W. J. White, Associate Member, has resigned from the position of Lecturer at the Cambridgeshire Technical College and has taken up an appointment with the United Kingdom Atomic Energy Authority, Aldermaston.

Mr. G. W. Wynn, Associate Member, is now Resident Engineer to Olympia Limited, London.

Mr. A. D. Mackay, Associate, is no longer Managing Director of the Bergius Company. He is now Managing Director of Henry Meadows Limited, Wolverhampton, and Deputy Chairman of the Bergius Company.

Mr. G. F. Brigginshaw, Graduate, has now joined Byron Business Machines, Nottingham, as Assistant General Works Manager. He was previously Assistant to Machine Shop Production Manager of The Mining Engineering Co. Ltd., Worcester.

news of members

Major H. V. Barker (Retd.) C.W.O.I., Member, has now left BAOR, and has taken up an appointment as officer-in-charge Main Shop, 41 Base Workshop, R.E.M.E., Singapore.

Mr. D. L. Deshpande, Member, has been appointed Director of Technical Education, Bihar, India.

Mr. F. C. Garner, Member, has been appointed Works Manager to S. C. Johnson & Son Limited. For the past six years Mr. Garner has been with Ultra Electric Limited, first as Works Manager and, latterly, as Executive Director of Manufacturing.

Mr. T. E. Love, Member, has retired from Messrs. Williams & James, Gloucester. He is Chairman of the Gloucester Section and a Corresponding Member of the Papers Committee.

Mr. G. C. Oram, Member, Manager of the Central Engineering Workshops at Appleby-Frodingham Steel Company, Scunthorpe, has been additionally appointed Technical Consultant, Engineering Works, to The United Steel Companies Limited. He remains responsible for the Central Engineering Workshops. Mr. Oram was head of the Government Engineering Works at Colombo, Ceylon, prior to returning to this country to serve throughout the War at Royal Ordnance factories. After holding executive appointments at the Royal Arsenal, Woolwich, and the R.O.F. at Radway Green, he joined Appleby-Frodingham Steel Company in April, 1946, in order to establish new Central Engineering Workshops there. Mr. Oram is Chairman of the Specialist group on Industrial Administration and Engineering Production at the Institution of Mechanical Engineers. He is also Chairman of the Lincoln Section of the Institution.

Mr. F. H. Perkins, Member, has recently relinquished his position as Chief Production Engineer at the Brush Electrical Engineering Co. Ltd., Loughborough to take up a new appointment as Advanced Planning Engineer with the Plessey Co. Ltd., Swindon.

Mr. R. Ratcliffe, M.B.E., Member, has been appointed Deputy Controller, Royal Ordnance Factories. The Royal Ordnance Factories, which have previously been in the charge of a Director-General reporting to the Controller of Munitions, will in future be under their own controller. Mr. Ratcliffe is Chairman of the Education Committee.

Mr. R. C. Shuster, Member, has been appointed Works Manager of E. H. Bentall & Co. Ltd., Maldon, Essex.

Mr. M. W. Alderdice, Associate Member, has relinquished his position with Vapalux Limited, and has taken up an appointment as a Consultant with Associated Industrial Consultants Limited.

Mr. K. C. Blackmore, Associate Member, is now a Project Engineer at the Atomic Energy Research Establishment, Harwell.

Mr. F. Bloor, Associate Member, has resigned his appointment as Senior Lecturer in Production Engineering at the Royal Aircraft Establishment Technical College, Farnborough, Hants, on being appointed Head of the Engineering Department and Vice-Principal of the Farnborough Technical College.

Mr. H. D. Buller, Associate Member, who was previously at Crossley Motors Limited, Stockport, has now taken up a position as Chief Production Engineer with Alvis Limited, Coventry.

Mr. J. Doyle, Associate Member, has relinquished his appointment as Lecturer at the College of Technology, Birmingham, and has taken up an appointment as Senior Lecturer in Production Engineering at the County Technical College, Wednesbury.

Mr. R. Gabriel, Associate Member, is now Sales Executive, Charles Churchill & Co. Ltd., Birmingham. He is also a Director of Churchill Gear Machines Limited, Newcastle-upon-Tyne ; Churchill Redman Limited, Halifax ; and Vertimax Limited, Glasgow.

Mr. S. H. Hibbert, Associate Member, is now Works Engineer at Reynolds Light Alloys Limited, Redditch.

Mr. E. C. Nicholson, Associate Member, has now taken up an appointment as a Production Engineer with the English Electric Co. Ltd., Rugby.

Mr. D. C. Northey, Associate Member, has relinquished his position as Senior Production Engineer for the C. E. Factory, E.M.I. Limited, Hayes, and has joined Messrs. Adcock and Shipley Limited, Leicester, as their Technical Representative for South East England.

Mr. F. Scammell, Associate Member, is now General Production Manager of Douglas (Kingswood) Limited, Bristol. He was previously Assistant Works Manager, Lines Bros. (South Wales) Ltd.

Mr. T. Turner, Associate Member, has relinquished his position of Works Engineer at Norton Motors Limited, Birmingham, to join Larcher Cutters Limited, Birmingham, as General Manager.

(concluded at foot of facing page)

Hazleton Memorial Library

REVIEWS & ADDITIONS

Members are reminded that copies of the Library Catalogue may be obtained from the Librarian, price 2/6d., plus 4d. postage (price to non-members, 10/-, plus 4d. postage).

REVIEW

" Modern Workshop Technology." Part 1 — " Materials and Processes " edited by H. Wright Baker. 2nd edition. Revised and enlarged. *London, Cleaver-Hume Press,* 1956. 511 *pages. Illustrated. Diagrams.*

The book under review is a new edition of the first part of the pair of books devoted to workshop technology originally published in 1948. This book is listed amongst the official text books for the Associate Membership examination of our Institution.

The book covers most of the pre-machine shop processes. Briefly these include: iron and steel, cast iron, heat treatment of steel, foundry practice, die casting, other casting processes, powder metallurgy, forging, drop forging, steel sheet, steel wire, bright steel, welding, aluminium and magnesium, nickel and nickel alloys, copper and its alloys, plastics engineering and, finally, mechanical testing and inspection of materials. The earlier edition has been augmented by additional information on iron and steel, spheroidal graphite iron, mechanised foundry work, shell moulding, investment casting, steel wire, bright steel bars and others.

This book has been written by 16 different authors, each a specialist in his own field. That status of the editor and contributors is such that one can accept the technical information in the book without question.

The preface merits special attention. The editor, in his characteristic style, has in a few hundred words, laid his finger on several of the fallacies of modern education and suggests that this book and its fellow are a contribution towards the solution inasmuch as it is technical material of a high standard being fed back to the colleges by industry.

The editor suggests that this is not a text book. This statement can only be accepted with certain reservations. Similar information is available for students in a digested form in several books on technology. At the other extreme, specialists can find complete books whose subject matter is covered by only a single chapter in the book under review. Many such books are mentioned in the bibliography. This book steers a course between these extremes. For the engineer from any age group, who wishes to improve his technical background, and for the student who has yet to acquire a technical background, the book is equally well recommended.

S.R.S.

OTHER ADDITIONS

British Gear Manufacturers' Association, Sheffield. **" Buyers' Guide."** *Sheffield, the Association,* 1955. 24 *pages.*

British Productivity Council, London. **" Brushes."** *London, the Council,* 1956. 24 *pages.* (Productivity Review.) 2s. 6d. Review of Productivity in the Brush Industry.

British Productivity Council, London. **" Freight Handling."** *London, the Council,* 1956. 46 *pages. Illustrated.* (Productivity Review.) 2s. 6d.

British Productivity Council, London. **" Fuel Conservation and Productivity."** *London, the Council,* 1955. 20 *pages.* 9d. (B.P.C. Action Pamphlet No. 5.)

British Standards Institution, London. **" British Standards for Steel and Steel Products."** *London, the Institution,* 1949. 674 *pages. Illustrated. Diagrams.* (B.S. Handbook No. 10.) 25s. Includes (1) Articles describing the manufacture of steel and steel products; (2) Summaries of the essential technical requirements of British Standards for steel and steel products; (3) Other information of general interest, e.g., methods of test, heat treatment designations and convertion factors.

Canada. National Research Council — Technical Information Service. **" Preventing Corrosion of Ships with Zinc and Magnesium Protectors ":** notes compiled by I. D. G. Berwick. *Ottawa, the Council,* 1955. 8 *pages. Diagrams.* (T.I.S. Report No. 44.) The notes are intended primarily for the information of small boat builders and tug operators, but the general principles outlined are not confined to marine applications.

Canada. National Research Council — Technical Information Service. **" Propane Gas for Metal Cutting "** by G. G. M. Carr-Harris. *Ottawa, the Council,* 1955. 12 *pages.* (T.I.S. Report No. 46.) A short introduction followed by an annotated bibliography.

Canada. National Research Council — Technical Information Service. **" Selected bibliography on Water Pollution caused by the Petroleum Industry "** by Muriel E. Whalley. *Ottawa, the Council,* 1956. 13 *pages.* (T.I.S. Report No. 47.)

Canada. National Research Council — Technical Information Service. **" Selected bibliography on Water Pollution caused by the Pump and Paper Industry "** by Muriel E. Whalley. *Ottawa, the Council,* 1956. (T.I.S. Report No. 48.)

Canada. National Research Council — Technical Information Service. **" Survey of Continuous Fermentation Processes" :** an annotated bibliography by Muriel E. Whalley. *Ottawa, the Council,* 1955. 29 *pages.* (T.I.S. Report No. 45.)

Chute, George M. **"Electronics in Industry."** 2nd edition. *New York, McGraw-Hill,* 1956. 431 *pages. Illustrated. Diagrams.* $7.50 dollars (56s. 6d.). The fundamentals of electronic devices for industrial applications. The material is arranged so that it can be used as a survey by students of

mechanical, chemical, civil or aeronautical engineering, and as a supplementary textbook by electrical engineering students. There are problems with answers appended to each chapter.

Cleveland. Public Library—Business Information Bureau. **"Atomic Energy for Peacetime Use":** an annotated bibliography. *Cleveland, the Library,* 1955. *Pages* 17 - 22. (Bulletin of the Business Information Bureau. Volume 26. No. 5.)

Dearden, John. **"Iron and Steel Today."** 2nd edition. *London, O.U.P.,* 1956. 271 *pages. Illustrated. Diagrams.* 12s. 6d. A popular account of all the technical aspects of the iron and steel industry.

Eisler, P. **"Printed Circuits and the Electronics Industry."** *London, Butterworth's Scientific Publications,* 1956. 12 *pages. Illustrated. Diagrams.* (Reprinted from *Research,* May and June, 1956.) "Printed circuits are rapidly replacing the slower and more conventional types of wiring. In Part 1 Dr. Eisler reviews the present position in the electronics industry and gives examples of the production of printed circuits. Part 2 . . . is devoted to the wider exploitation, including the manufacture and integration of components."

European Productivity Agency, Paris. **"Productivity Measurement." Volume 2 — "Plant Level Measurements, Methods and Results."** *Paris, O.E.E.C.,* 1956. (E.P.A. Project No. 235.) 194 *pages. Diagrams.* 3s. 6d.

European Productivity Agency, Paris. **"Report on the Second Meeting of Technical Information Officers . . . Frankfort . . . 1955."** *Paris, O.E.E.C.,* 1955. 85 *pages. Illustrated. Diagrams.* 3s. 9d. The Conference, which included delegates from 12 countries, studied technical information services of Germany, and discussed present and future projects of E.P.A. in the field of technical information.

Fogarty, Michael P. **"Personality and Group Relations in Industry."** *London, Longmans,* 1956. 341 *pages. Diagrams.* 30s. The author attempts to show how the smallest units in society — personalities — combine in working groups, and how the working groups are related to the wider community. The author claims that this approach to the study of industrial relations "from the inside out" is new.

Geary, P. J. **"Flexure Devices, Pivots, Movements, Suspensions":** a bibliographical survey. *London, British Scientific Instruments Research Association,* 1954. 44 *pages. Diagrams.* (B.S.I.R.A. Research Report M.18). Bibliography with technical introduction.

Handyside, John D. **"An Experiment with Supervisory Training."** *London, National Institute of Industrial Psychology,* 1956. 48 *pages. Diagrams.* (Report No. 12.) "This study set out to measure . . . the effects of introducing a supervisory training scheme in a firm where no previous systematic approach had been made to supervisory training." The firm is situated in the London area, and employs 1,250 people. One department was used as an experimental group and three others as control.

Houghton, P. S. **"Jig and Fixture Design."** *London, Chapman & Hall,* 1956. 256 *pages. Diagrams.* 36s. A comprehensive treatment of the subject, suitable for students. Questions and problems are given at the end of the book.

Hummel, Francis E. **"Making a Market Survey."** *Washington, Small Business Administration,* 1956. (Management Aids for Small Manufacturers, No. 73.)

Illinois. University — College of Commerce and Business Administration — Business Management Service. **"Using Aptitude Tests in Selecting Industrial Personnel"** by Robert L. Peterson. 8 *pages. Diagrams.* (Management Case Study.) An actual case study of an Illinois firm.

Institute of Cost and Works Accountants, London. **"Cost Reduction."** *London, the Institute,* 1956. 49 *pages. Diagrams.* 6s. This report of the Institute's Research and Technical Committee, surveys the subject of cost reduction in relation to: design, factory organisation and production methods, marketing, and finance.

Town, H. C., and Colebourne, R. **"Engineering Inspection and Testing."** *London, Odhams Press,* 1956. 191 *pages. Illustrated. Diagrams.* 21s. Explains the functions of a modern inspection department, and traces the development of standards and methods of measurement. Treats also the principles and practice of precision measurement; comparators and other measuring and inspection instruments.

United States of America — Department of Commerce — Office of Technical Services. **"Machining Studies by Radiometric Methods."** *Washington, the Department,* 1955. 24 *pages. Illustrated. Diagrams.* A report of wear studies by radiometric methods on high speed steel and carbide cutting tools.

Warburton-Brown, D. **"Induction Heating Practice."** *London, Odhams Press,* 1956. 192 *pages. Illustrated. Diagrams.* 21s. A handbook of the high-frequency induction process for all concerned with engineering production.

RESEARCH PUBLICATIONS

A number of copies of the following Research publications are still available to members, at the prices stated:

Machine Tool Research and Management	10/6
Report on Surface Finish, by Dr. G. Schlesinger	15/6
Practical Drilling Tests	21/-

These publications may be obtained from the Production Engineering Research Association, "Staveley Lodge", Melton Mowbray, Leics.

JOURNAL BINDERS

Strongly-made binders for the Institution Journal, each holding 12 issues, may be obtained from Head Office, 10 Chesterfield Street, London, W.1, price 10/6 each, including postage.

The Council of the Institution

1956/57

President
E. W. Hancock, M.B.E.

Vice-President
The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P.

Chairman of Council
H. G. Gregory

Vice-Chairman of Council
A. F. Kelley

Immediate Past Chairman of Council
G. R. Pryor

Past Presidents
Major-General K. C. Appleyard, C.B.E. Sir George Bailey, C.B.E. Sir Alfred Herbert, K.B.E. Sir Leonard Lord, K.B.E. The Rt. Hon. Viscount Nuffield, G.B.E. Sir Walter Puckey Norman Rowbotham, C.B.E. J. D. Scaife Dr. H. Schofield, C.B.E. The Rt. Hon. Lord Sempill, A.F.C. Sir Cecil Weir, K.G.M.G., K.B.E., D.L., M.C.

Presidents of Councils outside the United Kingdom
Australian Council—J. N. Kirby, O.B.E.
South African Council—D. S. Clare

Chairmen of Regional Committees

East & West Ridings
F. T. Nurrish, M.B.E.
Eastern
E. N. Farrar
Midlands
B. G. L. Jackman
North Midlands
A. S. Johnstone

Northern
J. W. Woodger
North Western
J. H. Winskill
Northern Ireland
J. G. Easterbrook
Scotland
A. Betts Brown

South Eastern
R. Telford
Southern
J. W. G. Pringle
South Western
W. U. Snell
Wales
W. H. Bowman

Additional Representatives on Council

East & West Ridings
J. E. Hill
Midlands
E. Percy Edwards

North Western
F. W. Cranmer
South Eastern
W. Edwards

Chairmen of Standing Committees
J. M. Brice B. H. Dyson A. A. J. Francis R. Ratcliffe, M.B.E. H. Stafford The Rt. Hon. Lord Sempill, A.F.C. F. Woodifield

Elected Members
G. R. Blakely H. W. Bowen, O.B.E. H. Burke A. E. Clifford H. H. Dawson F. J. Everest A. Griffiths, O.B.E. S J. Harley H. W. Hodson R. Hutcheson A. F. Kelley E. Levesley R. N. Marland L. S. Pitteway H. Spencer Smith A. L. Stuchbery C. Timms H. Tomlinson

Co-opted Member
T. Fraser, C.B.E.

Chairmen of Sections outside the United Kingdom where Councils are not established

Bombay
R. A. P. Misra
Canada
C. E. Barkworth

Calcutta
P. Bhattacharji
New Zealand
H. K. Pickering

Overseas Councils

AUSTRALIA

President
J. N. Kirby, O.B.E.

Chairman
J. O. Ogden

Vice-Chairman
C. J. Clark

Elected Members
J. W. H. Clarke R. W. Deutsher S. Downie N. Eaton N. Esserman P. E. Frye W. Gwinnett W. L. Hemer E. J. W. Herbert F. W. Penny C. Pullen J. Steer J. E. Strick H. G. Sutton L. W. Worthington

SOUTH AFRICA

President

D. S. Clare

Past Presidents

A. B. Anderson R. H. Arbuckle L. H. L. Badham W. G. Gillespie G. Godfrey H. J. G. Goyns J. Henry D. Lion-Cachet J. Renwick A. G. Wotherspoon

Elected Members

W. E. Bateman G. T. Chawner D. E. Hamm T. H. Hunter C. J. Mogford D. A. Petrie G. M. Pratley G. G. Tardrew H. H. Waters F. Westall

REGIONAL HONORARY SECRETARIES

East & West Ridings ...	J. L. Townend	**Northern Ireland**	W. G. Wyman
Eastern	L. A. Childs	**Scotland**	W. H. Marley
Midlands	B. W. Gould	**South Eastern**	R. Hutcheson
North Midlands	H. Wright	**Southern**	J. W. Taylor
Northern	R. G. Monkhouse	**South Western**	A. Eustace
North Western	J. P. Speakman	**Wales**	H. P. Sanderson

Secretary of the Institution

W. F. S. Woodford

SECTION CHAIRMEN

C. J. Clark	*Adelaide*
T. W. Elkington	*Birmingham*
R. A. P. Misra	*Bombay*
P. Bhattacharji	*Calcutta*
C. E. Barkworth	*Canada*
F. G. Robinson	*Cornwall*
W. G. Rootes	*Coventry*
A. G. Clark	*Derby*
W. J. Edgington	*Doncaster*
R. B. Thomson	*Dundee*
F. T. Dyer	*Eastern Counties*
A. Betts Brown	*Edinburgh*
J. Menzies	*Glasgow*
T. E. Love	*Gloucester*
W. A. Hannaby	*Halifax*
L. S. Pitteway	*Leicester*
G. C. Oram	*Lincoln*
J. H. Winskill	*Liverpool*
G. R. Blakely	*London*
W. Edwards	*Luton*
T. A. Stoddart	*Manchester*
C. Pullen	*Melbourne*
H. K. Pickering	*New Zealand*
H. B. Topham	*North Eastern*
J. G. Easterbrook	*Northern Ireland*
V. Crowther	*Norwich*
T. G. H. Middleton	*Nottingham*
J. W. G. Pringle	*Oxford*
W. E. Peck	*Peterborough*
F. Grimshaw	*Preston*
H. A. Richardson	*Reading*
W. T. Cottingham	*Rochester*
J. R. Widdowson	*Sheffield*
B. G. Williams	*Shrewsbury*
D. S. Clare	*South Africa*
P. H. W. Everitt	*South Essex*
W. Abraham	*South Wales*
D. L. Wiggins	*Southern*
H. A. Armstrong	*Stoke-on-Trent*
J. O. Ogden	*Sydney*
J. W. Woodger	*Tees-Side*
Capt. V. J. Sankey	*West Wales*
W. U. Snell	*Western*
G. A. Firkins	*Wolverhampton*
H. C. Banfield	*Worcester*
H. Crompton	*Yorkshire*

GRADUATE SECTION CHAIRMEN

R. C. Short	*Birmingham Graduate*
A. S. Hopkins	*Coventry Graduate*
H. Scholes	*Halifax Graduate*
D. R. Portman	*Liverpool Graduate*
D. J. Jerrard	*London Graduate*
R. St. John Aylieff	*Luton Graduate*
L. E. Chadderton	*Manchester Graduate*
P. J. W. Cottrell	*Melbourne Graduate*
T. Lewins	*North Eastern Graduate*
E. F. Free	*Rochester Graduate*
G. Shaw	*Sheffield Graduate*
J. E. Heape	*Western Graduate*
E. J. Lownes	*Wolverhampton Graduate*

SECTION HONORARY SECRETARIES

AUSTRALIA

Adelaide (South Australia) ...	W. L. Hemer, 6 Bedford Street, Brooklyn Park, South Australia.
Melbourne (Victoria, Australia)	R. W. Deutsher, Bank House, 11 Bank Place, Melbourne, C.I., Victoria, Australia.
Melbourne Graduate (Victoria, Australia)	D. F. McKelvie, 94 Taylor Street, Clayton, Victoria, Australia.
Sydney (New South Wales) ...	A. Welsh, Room 802, 16 Barrack Street, Sydney, Australia.

CANADA

Canada	P. M. Wood, 7 Tottenham Road, Don Mills, Ontario, Canada.

INDIA

Bombay	E. Fernandes, c/o Burmah Shell, Royal Insurance Bldg., 14 Jamshedji Tata Road, Churchgate, Bombay, India.
Calcutta	C. K. Haldar, Calcutta Technical School, 110 Surenda Nath Banerjee Road, Calcutta, 13.

NEW ZEALAND

New Zealand	G. Stedman, 3 Harrison Avenue, Belmont, Takapuna, Auckland, New Zealand.

SOUTH AFRICA

South Africa	A. Aitken, 2 Commerce House, 85 Simmonds Street, P.O. Box 10837, Cr. Wolmarans Street, Johannesburg.

UNITED KINGDOM

Birmingham	A. Colin Turner, 120 Addison Road, Kings Heath, Birmingham, 14.
Cornwall	F. G. Hawke, 17 Church Road, Pool, Redruth, Cornwall.
Coventry	A. S. Hopkins, 39 Oaks Road, Kenilworth, Warwickshire.
Derby	P. Warburton, 16 Vicarage Road, Chellaston, Derby.
Doncaster	J. F. Spencer, 236 Warmsworth Road, Doncaster, Yorks.
Dundee	J. Nicolson Low, Technical College, Bell Street, Dundee.
Eastern Counties	H. F. Harker, Ransomes, Sims & Jefferies Ltd., Orwell Works, Ipswich.
Edinburgh	W. Sinclair, Brown Bros. & Co. Ltd., Rosebank Ironworks, Edinburgh, 7.
Glasgow	W. H. Marley, G. & J. Weir Ltd., Cathcart, Glasgow, S.4.
Gloucester & District ...	C. L. Mawhood, 132 Brooklyn Gardens, Cheltenham.
Halifax	Miss N. E. Bottom, Hopkinsons Ltd., Huddersfield, Yorks.
Leicester & District	E. G. Davis, 19 Festival Avenue, Humberstone Lane, Thurmaston, Leics.
Lincoln	H. Wright, 101 Longdales Road, Lincoln.
Liverpool	R. T. Spencer, 44 Kremlin Drive, Stoneycroft, Liverpool, 13.
London	R. J. C. Whitaker, Glacier Metal Co. Ltd., Ealing Road, Alperton, Middlesex.
Luton	J. F. W. Galyer, Engineering Dept., Luton & South Beds. College of Further Education, Park Square, Luton, Beds.
Manchester	J. P. Speakman, 223 Douglas Road, Atherton, Nr. Manchester.
North Eastern	A. C. Foskew, 35 Oakwood Avenue, Low Fell, Gateshead, 9.
Northern Ireland	W. G. Wyman, Glenconway House, Glenavy, Co. Antrim.
Norwich	J. I. Hilder, 2a, Gorse Road, Thorpe, Norwich.
Nottingham	C. N. T. Manfull, Chellaston House, Thurgarton Street, Nottingham.
Oxford	E. A. Wootton, 8 Manor Road, Grimsbury, Banbury, Oxon.
Peterborough	N. Holmes, "Arncliffe," 11 Mary Armyn Road, Orton Longueville, Peterborough, Northants.
Preston	W. H. Preston, 25 Clifton Avenue, Leyland, Lancs.
Reading	R. W. H. Mark, 'The Beeches', 41 Reading Road, Woodley, Berks.
Rochester & District	W. G. Clements, 11 Charing Road, Gillingham, Kent.
Sheffield	T. F. Newton, 20 Exley Avenue, Sheffield, 6.
Shrewsbury	W. M. Buchan, Llanberis, 36 Mytton Oak Road, Shrewsbury.
Southern	J. W. Taylor, 44 Deacon Road, Bitterne, Southampton.
South Essex	D. S. Redhead, Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex.
South Wales & Mon. ...	J. G. Bolwell, Creed & Co. Ltd., Treforest Industrial Estate, Nr. Pontypridd, Glam.
Stoke-on-Trent	(Acting) A. McDonald, 'Kinross', 13 Leyfield Road, Trentham, Stoke-on-Trent.
Tees-Side	J. H. Cooper, 48 Cobb Hill Close, Saltburn-by-the-Sea, Yorks.
Western	A. Eustace, 19 Ferndale Road, Northville, Bristol, 7.
West Wales	H. P. Sanderson, I.C.I. Ltd., Metals Division, Waunarlwydd, Nr. Swansea.
Wolverhampton	R. J. Sury, Widdicombe House, 2 Buttons Farm Road, Penn, Wolverhampton.
Worcester	R. Wheeler, Old Farm House, 7 Parish Hill, Bournheath, Nr. Bromsgrove, Worcs.
Yorkshire	J. L. Townend, 26 Moor Allerton Drive, Street Lane, Leeds, 17.

CORRESPONDING MEMBER IN MIDDLE EAST

J. Merkine, 45 Arlozoroff Street, Ramat-Gan, Israel.

CORRESPONDING MEMBER IN IRAQ

W. G. Rooke, Production Engineer, Iraqi State Railways, Shalchiyah, Baghdad, Iraq.

CORRESPONDING MEMBER IN BRITISH WEST AFRICA

H. P. Halfter, Gold Coast Rlys. & Harbour Admin., P.O. Box 202, Takoradi, Gold Coast, B.W.A.

GRADUATE SECTION HONORARY SECRETARIES

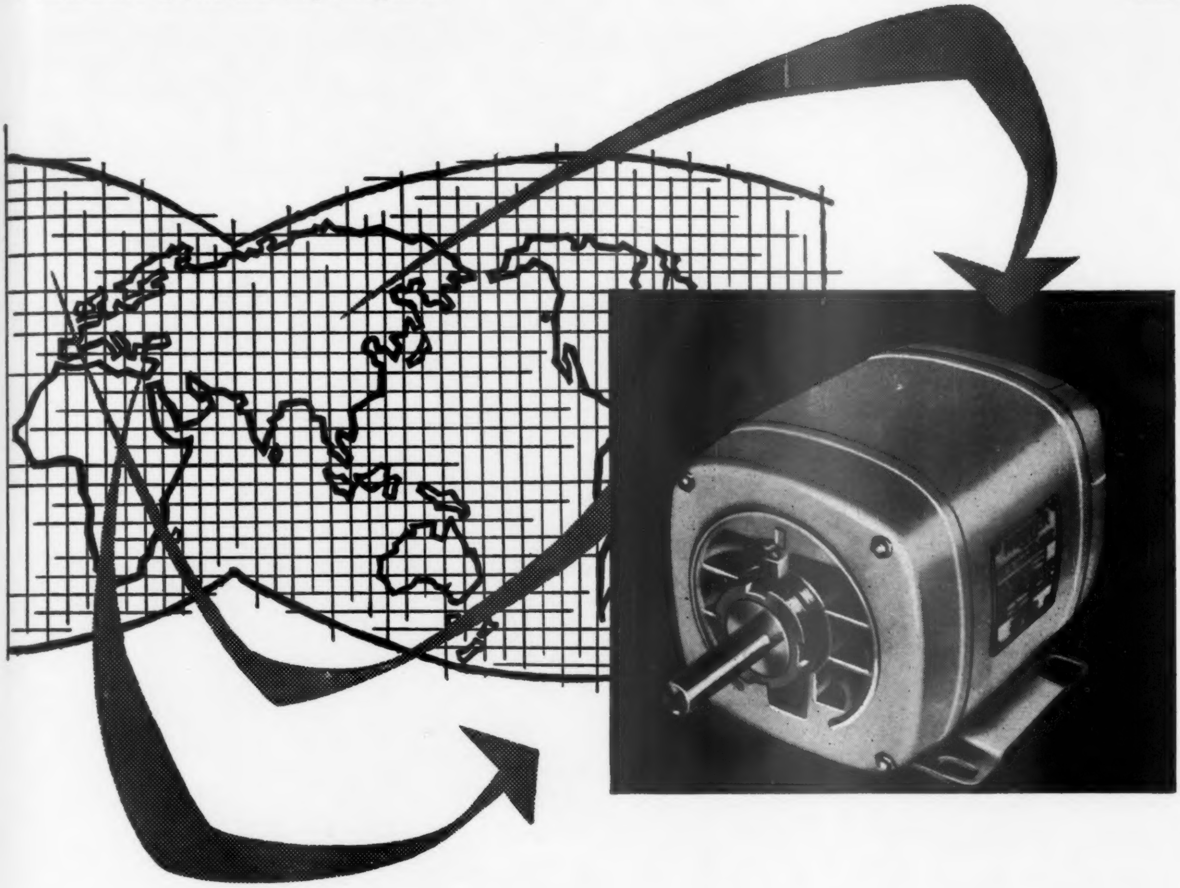
Birmingham	W. E. Hipkiss, 17 Briery Road, Halesowen, Birmingham.
Coventry	T. E. Fulker, 3 Thornton Close, Eastern Green, Coventry.
Halifax	C. W. Overin, 353 Whitehall Road, Westfield, Wyke, Nr. Bradford, Yorks.
Liverpool	G. L. Smith, 17 Withers Street, Liverpool, 7.
London	R. J. Temple, 59 Brooke Road, Stoke Newington, London, N.16.
Luton	C. Halton, 18 Churchill Road, St. Albans, Herts.
Manchester	R. C. Yarnell, 1 Demesne Road, Whalley Range, Manchester, 16.
North Eastern	R. Scott, 71 Monk Street, Gateshead, 8, Co. Durham.
Rochester & District ...	J. R. Anderson, 63 Watling Street, Strood, Kent.
Sheffield	M. D. Drinkwater, 26 Herdings View, Gleadless, Sheffield, 12.
Western	T. G. Mossman, Y.M.C.A., Colston Street, Bristol, 1.
Wolverhampton	W. L. Pace, 10 Ezekiel Lane, Short Heath, Willenhall, Staffs.
Yorkshire	(Acting) J. L. Townend, 26 Moor Allerton Drive, Street, Lane, Leeds, 17.

LOUGHBOROUGH COLLEGE STUDENT SECTION

Chairman: A. K. Windeler, Department of Industrial Engineering, College of Technology, Loughborough.
Secretary: S. K. Maini, Hazlerigg Hall, Loughborough, Leics.


Butler
26" SUPER SHAPER
THE BUTLER MACHINE TOOL Co LTD HALIFAX ENGLAND
BUTLER
Economical · Sturdy
Flexible in Toolroom
or Production Shop
The BUTLER MACHINE TOOL Co Ltd
HALIFAX ENGLAND
TELEPHONE 61641
MAKERS OF PRECISION
PLANERS
SHAPERS
SLOTTERS

B 301 A




ASQUITH
OD5
The NEW
RADIAL BORING MACHINE
for Extra Heavy Duty
Designed to provide exceptional rigidity and adequate power for the very heaviest of drilling and boring work.
Made in a range with maximum radius 8ft. up to 12ft.

MAXIRAPID

AUTOMATIC MULTI-TOOL LATHE

designed specifically for fully automatic high output production

Top illustration shows loading arm ready for automatic exchange of components between centres.

Lower illustration shows slides in cutting position. Unmachined components can be seen at the front of the loading unit. Machined parts are ejected at the rear of unit.

DRUMMOND BROS. LTD.

GUILDFORD · ENGLAND

The illustrations above show the "Maxirapid" tooled up for turning forged steel final-drive pinions. This example demonstrates the possibilities of the machine for really high speed heavy duty production.

Full advantage is taken of the adequate power and rigidity of the "Maxirapid", carbide tools being employed for all turning operations, and automatic loading and unloading is provided. Maximum swing over bed of the "Maxirapid" is 17 ins. and maximum distance between centres 24 ins. A 25, 35 or 50 h.p. motor can be fitted. The illustrations show the machine with splash guards removed.

Write today for a catalogue and get full details.

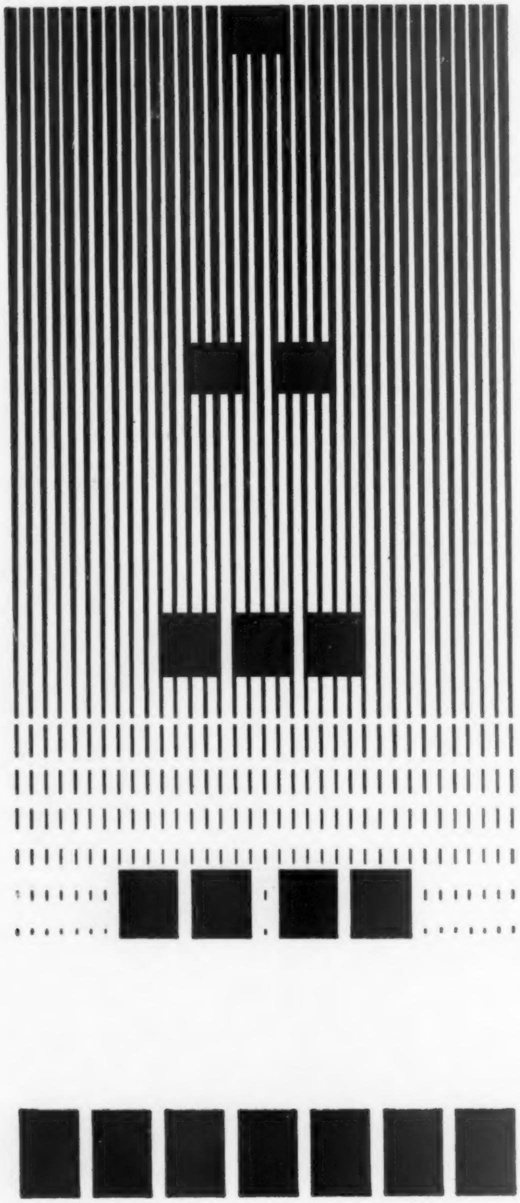
Sales & Service for ... **DRUMMOND-ASQUITH** *... the British Isles*

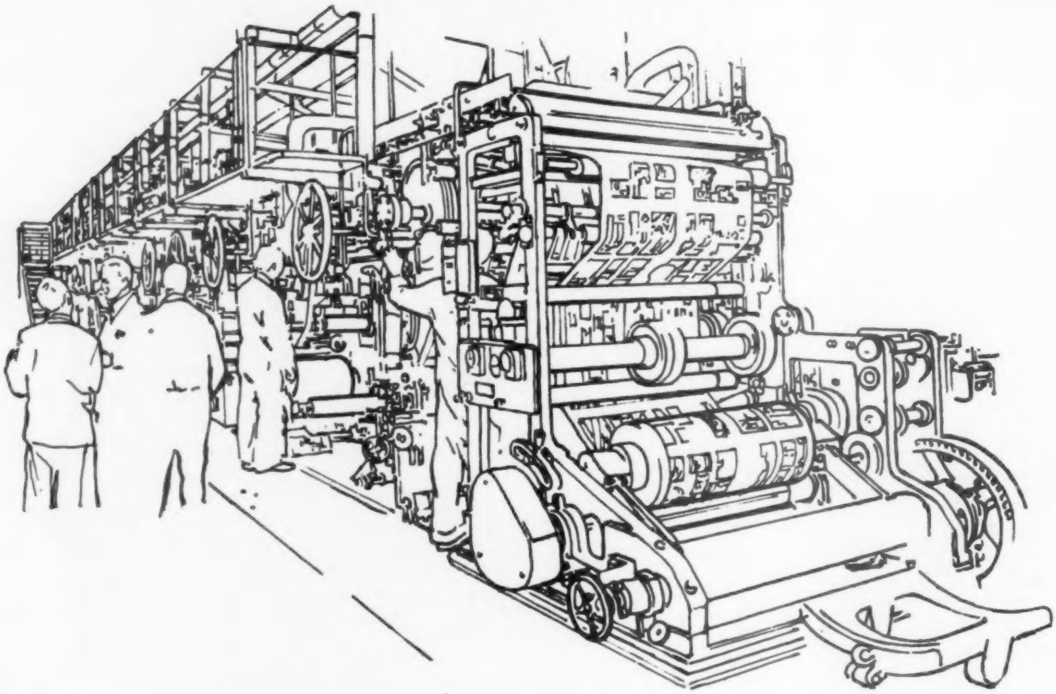
DRUMMOND-ASQUITH (SALES) LTD., KING EDWARD HOUSE, NEW ST., BIRMINGHAM

'Phone: Midland 3431 (7 Lines)

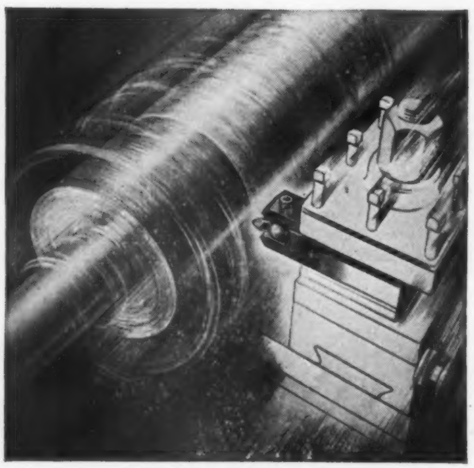
Also at LONDON: 'Phone Trafalgar 7224 (5 lines) and GLASGOW: 'Phone Central 3411

D157





the printer's diamond



The books you read depend to some extend on the diamond in their printing and production.

Diatipt Tools are used to produce the polished surface on copper printing rolls. They are also used for turning calender rolls and for surfacing rubber printing plates.

LM VAN MOPPES & SONS (DIAMOND TOOLS) LTD
BASINGSTOKE · HAMPSHIRE · ENGLAND

Telephone: Basingstoke 1240 Telegrams: Diatipt Basingstoke

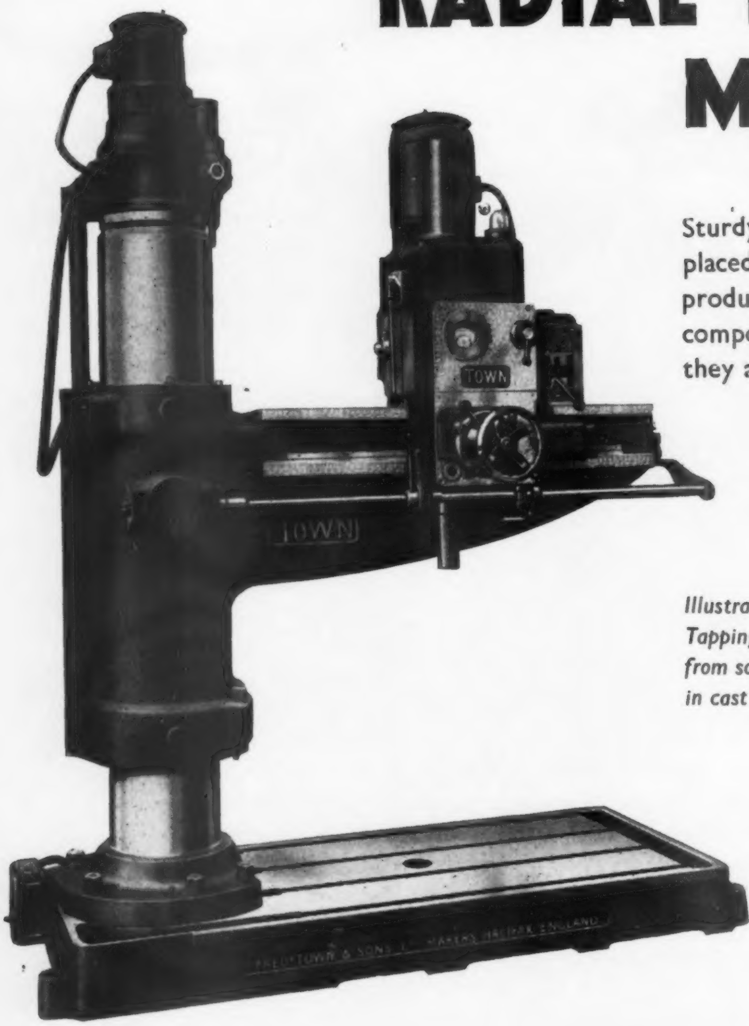
TRADE MARKS · DIATRU · DIANYF · DIATUF · DIATIPT · DIADUST · DIAFORM · DIADEX · DIATHREAD · DIATORC


count on me
for a quicker
take-off
I'll take-off at speed, complete the circuit at a really high rate of knots, old boy, and really keep the old shekels tinkling.
The Chief says I have a head for high speeds, electrically butt-welded to the shank.
The whole Group's like it—55 of us in all shapes and sizes—and everyone's available for a quick take-off right off the shelf.
We publish a monthly Duty Rota (Stock List to you)—why not have it sent?
JESSOP - SAVILLE
ARKWELD & TRIUMPHWELD
HIGH SPEED STEEL
BUTT-WELDED TOOLS
WM JESSOP & SONS LTD
BRIGHTSIDE WORKS SHEFFIELD
J J SAVILLE & CO LTD
TRIUMPH WORKS SHEFFIELD
Enquiries to:- SMALL TOOL WORKS, PORTLAND STREET, SHEFFIELD, 6.


WHY DO
C.T.B
NOZZLES OUTLAST
THEM ALL ?
Because the Carbon Tetra Boride lining is so far as we know the hardest man-made material commercially produced. Its resistance to abrasion, erosion and chemical action is greater than that of any other hard metal.
Glostics Ltd
AGENTS · IMPREGNATED DIAMOND PRODUCTS LTD
TUFFLEY CRESCENT · GLOUCESTER

TOWN

RADIAL DRILLING MACHINES



Sturdy, simple design, conveniently placed controls and maximum rates of production on the widest range of components—a few of the reasons why they are used all over the world.

Illustrated: Town 5ft. A.E.4 Radial Drilling, Boring, Tapping and Studding Machine. Drilling capacity from solid 2½in. diameter in steel and 3in. diameter in cast iron. Tapping 1¼in. Whitworth in steel.

FREDERICK TOWN & SONS LTD

HALIFAX · YORKS

T.2


For SIMPLICITY of HANDLING,
WIDE SPEED RANGE
and VERSATILITY
Archdale
38" SENSITIVES
Here is the baby of the range, showing the paces on a nickel chrome steel cylinder head. The International Harvester Co. Ltd., of Doncaster, find the spot facing and tapping of 8" × ½" diameter holes reduced to child's play on the ARCHDALE 38". Jobs of this sort show the ease and speed of operation of these handy little machines to good advantage.
The 38" will drill up to 1" dia., in M.S. and has a spindle speed range of 129—1627 R.P.M. Write for details.
JAMES ARCHDALE & CO., LTD.
BIRMINGHAM 16 · SOLE SELLING AGENTS : ALFRED HERBERT LTD. COVENTRY

SAVE 90% TOOLMAKERS COSTS!

Group of punches mounted in punch-holder with CERROMATRIX.

Section through punch-holder assembly showing simple "anchorages" between CERROMATRIX and holder-ring, and CERROMATRIX and punches.

135 HRS *cut to* 13 HRS

By orthodox methods, it took 135 hours to turn and mill the punch holder, and fit the punches in this tool shown by courtesy of Joseph Lucas Limited. Using Cerromatrix the time was cut to 13 hours.

LOW-TEMPERATURE MELTING ***EXPANDING***

CERROMATRIX ALLOY

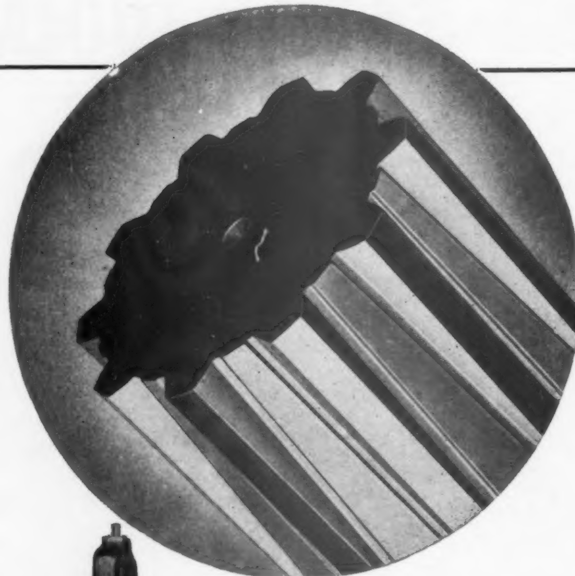
Cerromatrix is simple to use. It eliminates the need for complicated holding devices. It allows fast and accurate location of blanking, piercing and trimming punches without machining non-working surfaces. Time-savings range from a few hours to weeks depending on the complexity of the required die ; and tools made in this manner are still in use after blanking over a million pieces!

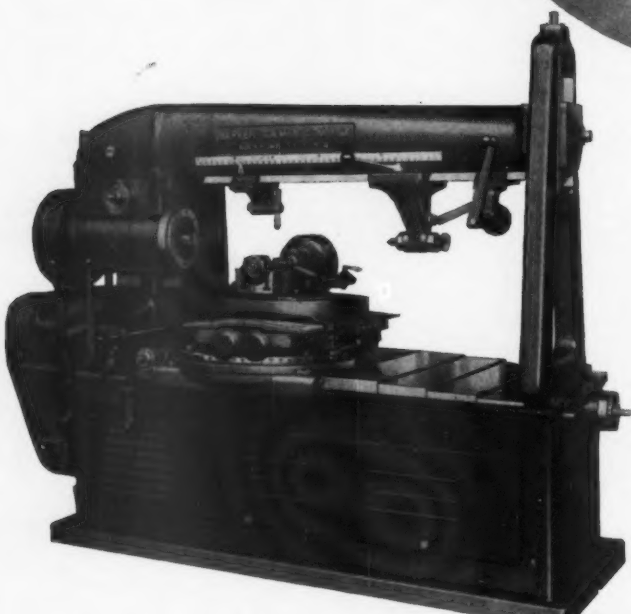
Write for **CERROMATRIX** *manual today!*

MINING & CHEMICAL PRODUCTS LTD · 86 STRAND LONDON WC2 · Telephone TEMPLE BAR 6511

another BARBER-COLMAN *development*

THE TAPER CORE SPLINE





Involute or straight-sided TAPER CORE keys for

- Greater strength.
- Metal-to-Metal contact.
- Accurate location of Mating parts.
- Greatest security under reciprocating stresses.
- Provides greater area of key contact.
- Saves time and work in assembling a product.
- Eliminates chance key failure.
- Mating parts produced simply by broaching a tapered reamed hole.

B-C MODEL 16-11 HOBBING MACHINE
Although designed primarily for hobbing taper splines on shafts, this machine may also be used for general purpose hobbing.

It is the ideal machine for the manufacturer who desires to improve his product by applying taper splines, eliminating the necessity of buying a special machine which could otherwise not be used for general work.

BARBER & COLMAN LTD. MARSLAND ROAD, BROOKLANDS, MANCHESTER

Telephone: SALE 2277 (4 lines) Telegrams: "BARCOL", SALE


There are bars
and bars . . .

FISHOLOW

Materials Handling
Service to Industry . . .

FISHOLOW engineers are ready to advise you on materials handling or storage problems of all kinds

FISHER & LUDLOW LTD · MATERIAL HANDLING DIVISION · BORDESLEY WORKS
BIRMINGHAM, 12. Tel.: VICtoria 2371

Also at LONDON, MANCHESTER, CARDIFF, GLASGOW, NEWCASTLE-ON-TYNE, BRISTOL, BELFAST and DUBLIN

Cheapest in the Long Run

Fitted in minutes without dismantling machinery. Stocks of belting can be reduced by 90%. Five coils of "BRAMMER" will replace 295 standard sizes of solid endless ropes.

Tested, pre-stretched and matched belts available from stock.

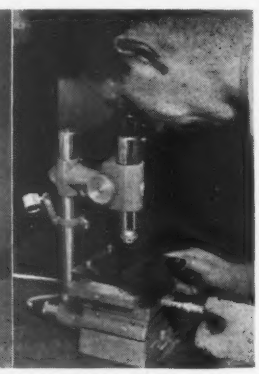
Coloured studs identify "BRAMMER" 40° angle sizes. The original and only rubber V-link belt which has been tested and proved for over 25 years.

V-Link BRAMMER belting

FLEXIBLE NON-SLIP TRADE MARK BRAMMER BELTING ENDLESS

H. BRAMMER & CO. LTD. HUDSON RD. LEEDS 9

E/4'



WATTS

Engineer's Universal Microscope

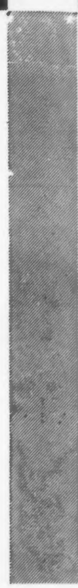
One Microscope with a hundred and one uses. Made on the unit principle, it can be adapted for the job whether simple inspection, angular or co-ordinate measurement. Ideal for measurement at the bench, on the lathe or in the inspection room.

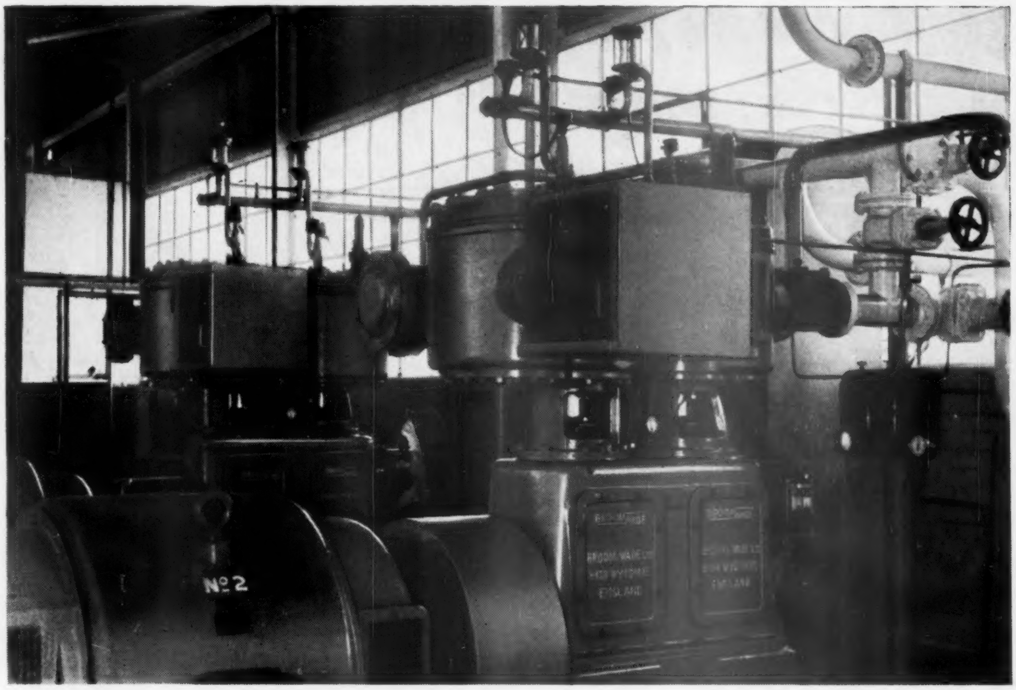
Write for List JPE/29E for further details.

HILGER & WATTS LTD

98, St. Pancras Way, London, N.W.1

Member of the Export Marketing Company—BESTEC





"BROOMWADE"

helps build cars in Australia

"BROOMWADE" air compressors and pneumatic tools play an important part in the manufacture of Nuffield cars at the British Motor Corporation's Sydney works.

The illustration shows two of a group of four TS1B units. In addition, the installation includes three D22A compressors which have been in regular use for six years.

The performance of these machines has been so satisfactory that a further order has been placed. This time for four TS2X units, each having an output of 1,000 c.f.m.

"BROOMWADE" pneumatic equipment saves time and reduces costs for most industries.

VISIT OUR STAND AT THE
PUBLIC WORKS & MUNICIPAL SERVICES EXHIBITION
OLYMPIA
12-17 NOV. 1956

PUBLIC WORKS & MUNICIPAL SERVICES

"BROOMWADE"

Aids Industry

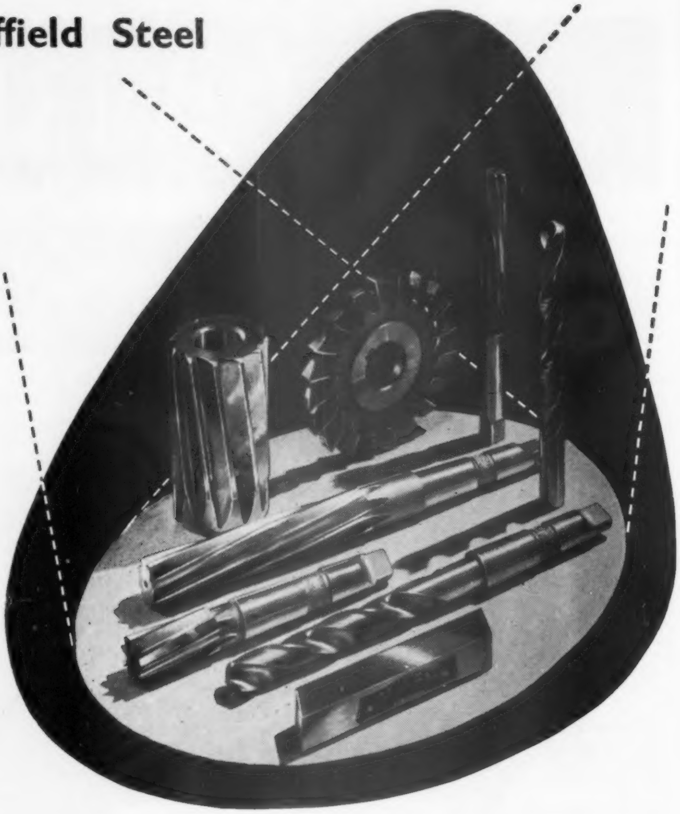
BROOM & WADE LTD., P.O. BOX No. 7, HIGH WYCOMBE, ENGLAND.

Telephone: High Wycombe 1630 (10 lines) *Telegrams: "Broom", High Wycombe, Telex.*

410 SAS

Three Centuries of Sheffield Steel

Here is a selection from the wide range of MARSH CYC High Speed and MARSH Carbon Steel Engineers' Tools. These tools, with MARSH Steels and Wire, are used by Government Departments and firms with household names, at home and abroad. We are a family firm, founded in 1631, and have a proud tradition of personal service to our customers the world over. MAY WE HELP YOU ?



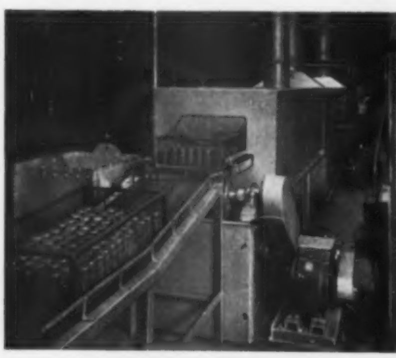
MARSH BROTHERS

of Sheffield England

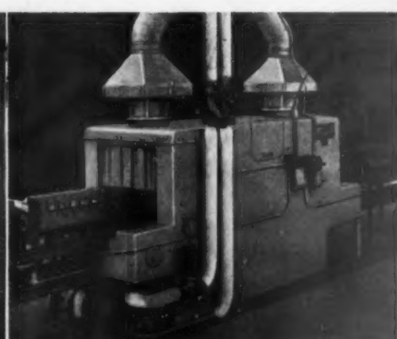
The most practical plant for Cleaning METAL PARTS

PRIOR TO ASSEMBLY, and BEFORE and AFTER REPAIRS

A 'Junior' type machine supplied to a Midland Motor Car Works.



Supplied for the washing and drying of Tractor parts. Crank Shafts, Sumps, Pressings, etc.



A model 'A' machine, washing parts of motor car engines prior to assembly.

Dawson

DE-GREASING AND CLEANING MACHINES

A Rotary Drum machine for removing swarf and grease from small components.

Dawson Metal Parts cleaning machines are supplied for all branches of the engineering industry. Their chief characteristics are robustness of design, small number of working parts and simplicity of operation. Space only permits the illustration of four of the many types of machines built for quick economical washing and drying of Metal Parts.

Sole Distributors

DRUMMOND - ASQUITH (Sales) LTD., King Edward House, New St., Birmingham

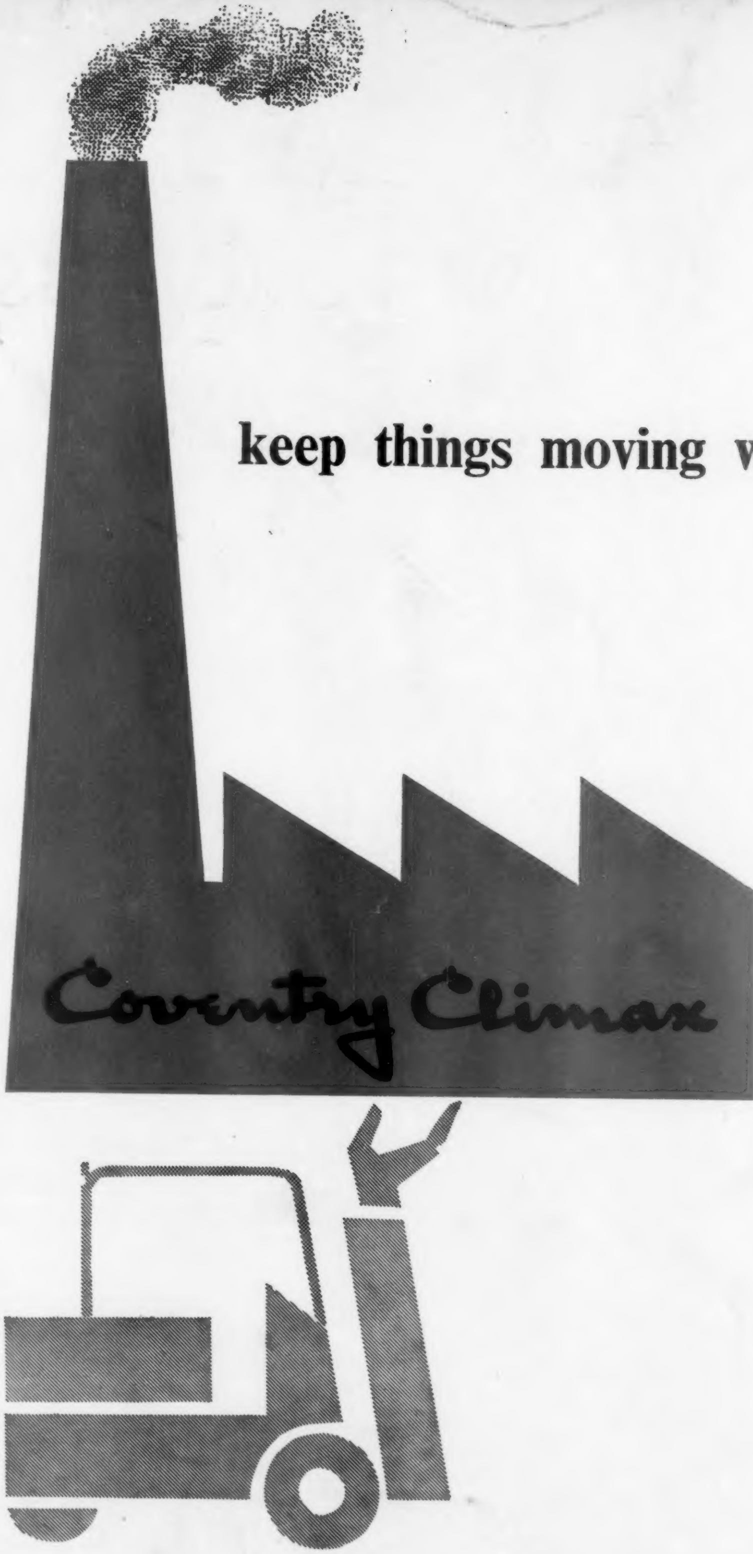
Telephone—Midland 3431

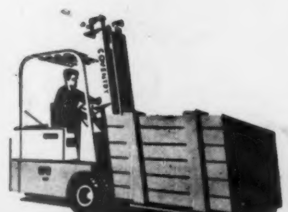
Manufacturers—DAWSON BROS. LTD., Gomersal, LEEDS Tel.—*Cleckheaton 1080 (5 lines)*

London Works—406 Roding Lane South, Woodford Green, Essex. Tel.—*Wanstead 7777 (4 lines)*

INDEX TO ADVERTISEMENTS

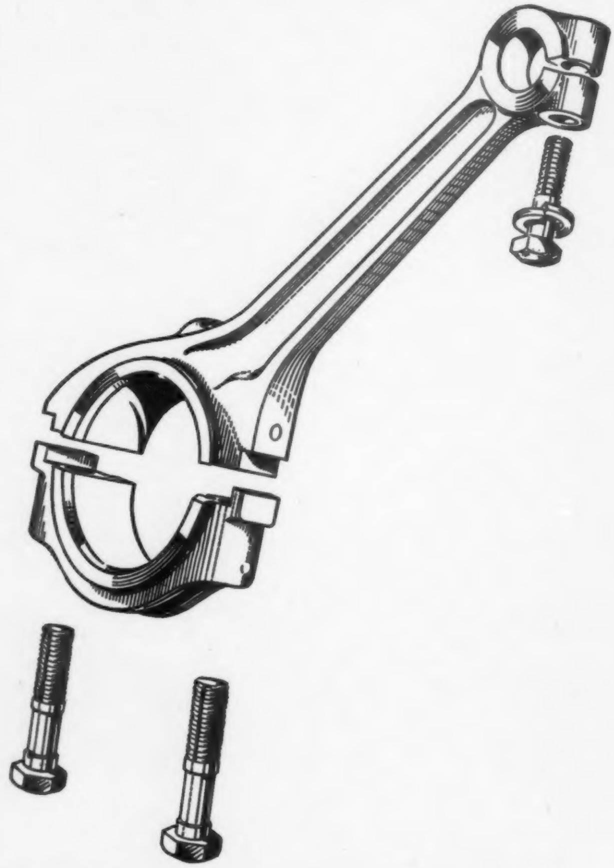
Printed by Maxwell, Love & Co. Ltd., White Lion Street, London, N.1


Coventry Climax



PARK GATE

QUALITY STEELS FOR DROP FORGINGS



black bars

for

connecting rods

THE PARK GATE IRON & STEEL COMPANY LIMITED ROTHERHAM

TELEPHONE: ROTHERHAM 2141 (10 lines) TELEGRAMS: YORKSHIRE, PARKGATE, YORKS